REPORT TO THE CONGRESS

FROM THE PRESIDENT OF THE UNITED STATES

UNITED STATES AERONAUTICS AND SPACE ACTIVITIES

1965

NASA DOD AEC STATE NSF COMM. NAS SAO FAA FCC USIA

REPORT TO THE CONGRESS

FROM THE PRESIDENT OF THE UNITED STATES

EXECUTIVE OFFICE OF THE PRESIDENT

NATIONAL AERONAUTICS AND SPACE COUNCIL

WASHINGTON, D. C. 20502

TO THE CONGRESS OF THE UNITED STATES

The record of American accomplishments in aeronautics and space during 1965 shows it to have been the most successful year in our history.

More spacecraft were orbited than in any previous year. Five manned GEMINI flights were successfully launched.

Our astronauts spent more hours in space than were flown by all of our manned spacecraft until 1965. Ten astronauts logged a total of 1297 hours 42 minutes in space.

The five manned flights successfully achieved included a walk in space, and the first rendezvous between two manned spacecrafts.

A scientific spacecraft completed a 325-million-mile, 228-day trip to Mars. MARINER 4 thereby gave mankind its first close-up view of another planet.

The RANGER series, begun in 1961, reached its zenith with two trips to the moon that yielded 13,000 close-up pictures of that planet. The entire RANGER series produced 17,000 photographs of the moon's surface which are being studied now by experts throughout the world.

Equally important were the contributions of our space program to life here on earth. Launching of EARLY BIRD, the first commercial communication satellite brought us measurably closer to the goal of instantaneous communication between all points on the globe. Research and development in our space program continued to speed progress in medicine, in weather prediction, in electronics -- and, indeed, in virtually every aspect of American science and technology.

As our space program continues, the impact of its developments on everyday life becomes daily more evident. It continues to stimulate our education, improve our material well-being, and broaden the horizons of knowledge. It is also a powerful force for peace.

The space program of the United States today is the largest effort ever undertaken by any nation to advance the frontiers of human knowledge. What we are discovering and building today will help solve many of the great problems which an increasingly complex and heavily-populated world will face tomorrow.

The year 1965 -- the year of GEMINI, RANGER, and MARINER -- is a brilliant preface to the coming years of APOLLO, stations in space, and voyages to the planets. I have great pride and pleasure in transmitting this remarkable record to the Congress that, through its enthusiastic support, has made possible.

Lyndon B. Johnson

THE WHITE HOUSE
January 31, 1966

TABLE OF CONTENTS

Chapter	I	U.S. Aeronautics and Space Activities -- 1965 Summary	1
Chapter	II	National Aeronautics and Space Council . .	5
Chapter	III	National Aeronautics and Space . . . . Administration	9
Chapter	IV	Department of Defense	49
Chapter	V	Atomic Energy Commission	69
Chapter	VI	Department of State	75
Chapter	VII	National Science Foundation	81
Chapter	VIII	Department of Commerce	85
Chapter	IX	Space Science Board	97
Chapter	X	Smithsonian Astrophysical Observatory . .	103
Chapter	XI	Federal Aviation Agency	107
Chapter	XII	Federal Communications Commission . . .	117
Chapter	XIII	United States Information Agency	121
Chapter	XIV	Arms Control and Disarmament Agency . .	127
Appendix	A-1	U.S. Launching Record (Chart)	129
Appendix	A-2	U.S. Launching Record (Table)	130
Appendix	A-3	Successful U.S. Launches - 1965	131
Appendix	B	SNAP Radioisotopic Electric Power Units for Space	161
Appendix	C	Listing of Major Space "Firsts" Achieved by the U.S. and the U.S.S.R.	162
Appendix	D	U.S. Space Launch Vehicles	164
Appendix	E-1	Historical Summary and FY 1966 Budget Recommendations (New Obligational Authority)	166
Appendix	E-2	Historical Summary and FY 1966 Budget Recommendations (Expenditures) . . .	167
Appendix	E-3	Space Activities Budget	168
Index		. . . .	169

CHAPTER I

U. S. AERONAUTICS AND SPACE ACTIVITIES *1965*

SUMMARY

The record of 1965 revealed the highest point yet reached in this Nation's upward trend of space accomplishment over the past eight years. The largest number of spacecraft was successfully orbited; the Moon and Mars were photographed at close range; manned flight activities reached new peaks; space competence was increasingly devoted to providing immediate benefits for mankind; our national security was augmented; and the technological, scientific, and managerial capabilities of the Nation were enhanced.

It will be indeed a challenge to guide the country during 1966 to levels of space progress which will exceed or even equal those attained in 1965.

In manned space flight, the year was particularly impressive. Five manned GEMINI spacecraft were put into orbit by TITAN II launch vehicles, as the United States flew more manned hours in space than had been flown by Soviet spacecraft throughout the history of their program and by U.S. spacecraft up until 1965. In addition to these long-duration flights, highlights of the manned space flight program for the year were the extra-vehicular activity and the rendezvous of two GEMINI vehicles in space. Progress in the APOLLO project gave encouraging indications that the schedule for this major achievement would be met. Also, in 1965, the President announced the decision to move forward with the development, testing, and flight of the Manned Orbiting Laboratory (MOL) and assigned the responsibility for that project to the Department of Defense.

The record for the year shows important progress with a variety of unmanned scientific spacecraft flights. RANGER spacecraft televised to Earth some 13,000 photographs, which, when added to the pictures taken in 1964, gave this country more than 17,000 photographs of the Moon's surface and furnished significant new knowledge of the lunar environment. MARINER completed a 325 million mile trip during a 228-day journey to Mars and returned the first close-up photographs of its surface and provided much new scientific information on that planet. Three PEGASUS satellites were launched during the year and have returned useful information regarding the intensity and number of meteoroid impacts. The second Orbiting Solar Observatory (OSO) was orbited with six experiments operating successfully, the second Orbiting Geophysical Observatory (OGO) was orbited, and the PIONEER satellite reported new data from interplanetary space.

The first commercial satellite (EARLY BIRD) was put into synchronous orbit for the Communications Satellite Corporation. Also, effective application of space knowledge was continued with an expansion of our weather satellite system (TIROS), navigational satellite system, geodetic satellites and nuclear explosion detection satellite system (VELA).

The program of the SATURN I, with its 1-1/2 million pounds of thrust, was completed with ten successful launches in ten attempts. Ground tests progressed for the more powerful SATURN IB and the SATURN V launch vehicles, while a major development took place on schedule with three successful launches of the 2.4 million pound thrust TITAN IIIC rocket. Encouraging progress in the testing of the NERVA nuclear reactors was made, and initial testing was successful for the more advanced PHOEBUS nuclear reactor. Another propulsion milestone was reached with the ground test firing of the world's largest solid propellant rocket motor when 3.5 million pounds of thrust was attained from the 260-inch engine. Also, the first nuclear space reactor (SNAP 10A) was orbited and produced practical evidence of the potential of atomic power as an energy source in space.

Cooperation with other nations in space progress continued during the year. The ALOUETTE was orbited for Canada and the FR-1 for the French. These were part of a growing program of international cooperation in space which includes mutually beneficial relations with about 70 nations. The space program became an even more effective arm of foreign policy when experienced astronauts were sent on educational and goodwill visits to a number of nations around the world. Particularly important was a decision announced by the President that efforts would be undertaken by high-level officials to expand cooperative space activities with nations in Europe.

The past year saw the realization of efforts to accelerate research, development, and initial operational use of a variety of aircraft for both civil and military applications. Advanced aeronautical research activities resulted in new world speed and altitude records by the United States, as well as the accumulation of much useful data on hypersonic flight. Valuable experience continued to accumulate through flights of the XB70s. An expanded effort in V/STOL aircraft development brought the potential application of this very useful aircraft type much closer to fruition. Significant advances took place in the field of large transport planes through design refinement and wind-tunnel testing of the supersonic transport concept and the decision to build the huge new C-5A military transport aircraft. Parallel development of a civil version of the C-5A and the supersonic transports can form the basis for great advances in the large scale use of the airplane for the long-range transportation of peoples and goods.

While the United States was building an impressive record as it orbited more spacecraft than any other nation, the U.S.S.R. was far from idle. In fact, during the year, that nation almost doubled its earth-orbiting activities over the previous year compared with a 36% increase for the United States. The Soviets also showed their determination to speed their space program as they more than doubled the U.S. activity in lunar and planetary exploration during the year.

Among the many major accomplishments by the United States during 1965 were the following:

... The five successful manned GEMINI flights produced a number of major achievements, such as the first U.S. two-man mission; the first U.S. extra-vehicular activity; the world's first eight-day and subsequently 14-day manned space missions; and the world's first sustained rendezvous between two manned spacecraft, in which they came within one foot of each other and flew in formation for nearly five hours.

... The Department of Defense was directed to proceed with the development of the Manned Orbiting Laboratory (MOL) at a development cost of about $1.5 billion with manned launches possible in 1968.

... The world's first commercial communications satellite (EARLY BIRD I) was successfully orbited.

... The TITAN IIIC, developing 2.4 million pounds of thrust, successfully accomplished its first flight test.

... The final three SATURN I flights were successfully conducted.

... All three stages of the 7.5 million pound thrust SATURN V were successfully test-fired.

... The decision was made to develop and produce 58 units of a revolutionary huge military transport aircraft C-5A) at a cost of about $2 billion over a period of about five years.

... The RANGER lunar photographic missions provided more than 17,000 high resolution pictures of the Moon's surface.

... MARINER IV flew past Mars, supplying 21 clear photographs and other data on that planet.

... Experimental military communications satellites were placed into orbit.

... The TIROS IX weather satellite was orbited with a cartwheel design, which will serve as the basis for the Weather Bureau's TIROS Operational Satellite System.

... GEOS, an advanced satellite devoted to geodetic studies, was orbited, as were several smaller geodetic satellites.

... Two more VELA satellites joined four VELAs already in orbit increasing the U.S. satellite based nuclear test detection capability for surface, high altitude, and deep space nuclear tests.

... A second Orbiting Solar Observatory (OSO) and a second Orbiting Geophysical Observatory (OGO) were orbited.

... The first of four new PIONEER spacecraft was orbited to transmit data on interplanetary space from as far away as 50 million miles.

... Research was continued on earth-based anti-satellite systems.

... The Navigation Satellite System continued to increase the accuracy of fixes given to U. S. Navy ships at sea, and lower-cost receiver developments were undertaken so as to make it possible to provide economical service to the merchant marine.

... Investigations were conducted by GEMINI astronauts of the effects of outer space on living matter, and plans were formulated for launch of the first BIOSATELLITE late in 1966.

... The effort to develop a Supersonic Transport reached the design and wind-tunnel test phase.

... Work continued on the counterinsurgency (COIN) aircraft and on the improvement of helicopters.

... The second XB-70 made its first flight and subsequently flew at Mach 3.

... The three X-15 research rocket airplanes completed 32 flights, conducting studies providing new information about hypersonic flight.

... Three PEGASUS satellites were launched furnishing significant information on the meteoroid hazards to spacecraft.

... The first 260-inch diameter solid propellant motor was successfully ground test-fired, producing a peak thrust of 3.5 million pounds.

... Three NERVA reactor experiments were successfully conducted, accumulating a total of more than 60 minutes of operation.

... A PHOEBUS nuclear propulsion reactor experiment was carried out, with the assembly operating at full power for about ten and one-half minutes.

... A KIWI-Transient-Nuclear test was conducted, with the results demonstrating a high level of safety for personnel at the launch site and elsewhere.

... The decision was made to proceed with the design of a 50-watt isotope generator (SNAP 27) for the APOLLO Lunar Surface Experiment Package, which will be left behind by astronauts after the first lunar landing.

... The ALOUETTE II, a Canadian satellite, was launched into orbit.

... The first satellite to be launched in cooperation with France (FR-1) was successfully orbited.

... ATLAS-CENTAUR, the vehicle assigned to launch instrument packages (SURVEYOR) for soft-landing on the moon, delivered a dummy craft to an imaginary moon 240,000 miles out in space.

... The U.S. launched 97 payloads into earth orbit and on lunar and solar trips.

NATIONAL AERONAUTICS AND SPACE COUNCIL

CHAPTER II

Nineteen sixty-five was a year of outstanding progress in both aeronautics and space. The record was particularly impressive in space flight and in space cooperation -- the latter both interagency and international.

This Nation's space achievements during the year were so distinctive in quality and quantity as to cause people, at home and abroad, to conclude the United States had attained the space leadership of the world. In many respects, that conclusion is accurate, but it would be incorrect and unwise to minimize the vitality and size of the space program of the U.S.S.R. During the year, the U.S. successfully placed into earth orbit 94 spacecraft as compared with 66 by the U.S.S.R. This was an increase over last year of 36 percent for the U.S. and 83 percent for the U.S.S.R. In fact, the Soviets almost doubled their earth orbiting activity over the previous year and, with their seven escape mission flights, more than doubled the U.S. activity in lunar and planetary exploration for the year. It is apparent that the U.S.S.R. has determined as a matter of policy that the benefits from space activity are sufficiently great to justify expanded performance.

In carrying out the responsibilities of the National Aeronautics and Space Council, attention was directed toward developing perspective so as to discourage complacency regarding international space competition and to encourage policies which would promote international space cooperation. In the latter respect, the space program can and does contribute importantly to peace and progress by extending cooperative international programs to about 70 nations around the world. Such relationships include but are not limited to the launching of payloads for other nations, the construction and operation of tracking facilities in other countries, the international exchange of scientific and engineering data, and the extension abroad of educational assistance. The mutual benefits of such cooperation prompt an expansion of this type of activity in the coming years.

During 1965, the space program became an even more effective arm of foreign policy when experienced astronauts were sent on educational and good will visits to a number of nations around the world. In one instance, the Vice President, who is also Chairman of the National Aeronautics and Space Council, was accompanied by several astronauts in an effective visit to the Paris Air Show.

Both nationally and internationally, the space program is dynamic and constructive in nature. Whether one looks at the actual construction of facilities, rockets, spacecraft, tracking stations, and other material assets, or whether one examines the output of new materials, the advances in electronics and other major skills, and the creation of new productive processes, the space program has matured into a positive force for economic and technical growth. Through direct applications of technology in such fields as communications, meteorology, navigation, and biomedical instrumentation, space competence is contributing to the betterment of our life here on earth.

It is a responsibility of those engaged in the space program to explore diligently the ways in which such activity can raise standards of living and advance understanding. In seeking benefits, it is necessary to look not only to the scientific, technical, educational, and military assets which flow directly from space performance itself, but also to the ways and means in which this growing technical competence can be effectively applied to the solution of the many other problems which confront this complex society.

Those who look thoughtfully and carefully at the national space program recognize clearly that it is still in its infancy. It is reasonable to predict that much growth lies ahead. It has been only a little more than eight years since the very first spacecraft was put into orbit. To date, the U.S. has orbited about the earth some 342 payloads. This includes six joint efforts with other countries, i.e. two with Canada, two with the United Kingdom, one with Italy, and one with France. Another 151 payloads have been launched successfully by the U.S.S.R. and one by France. In addition, the United States and U.S.S.R. have put 28 spacecraft (13 by the U.S. and 15 by the U.S.S.R.) on the moon or in orbit about the sun.

In 1965, further advance was made toward greater competence in manned space flight, with the President's announcement of a decision to move forward with the development, testing, and flight of the Manned Orbiting Laboratory. This project is intended to broaden the scope of man's pursuit of greater security through the extension of his peaceful activities in space. The Manned Orbiting Laboratory is not a weapons system; it is not a means by which aggressive actions can be perpetrated; and it is in no way in conflict with the established peaceful policies of the United States.

In the discharge of its responsibilities, the Council, directly and through its staff, engaged in a broad range of policy, coordinating, and informational activities. Among these were:

a. supervised the preparation of the President's Annual Report to the Congress on Aeronautics and Space Activities for 1965.

b. submitted regular reports to the President on significant space activities and plans.

c. increased public understanding of the national space program through speeches, articles, correspondence, and other public contacts.

d. participated in the analysis of various aspects of the FY 1967 budget for space and aeronautics.

e. examined the problems and alternative solutions regarding the development of space rescue capabilities.

f. coordinated on behalf of the President the decision to launch nuclear power satellites into space.

g. participated in the formulation and development of communications satellite practices and policies.

h. helped coordinate the necessary actions to make available international high frequency communications channels for GEMINI flights and recovery operations.

i. reviewed plans and policies affecting the Manned Orbiting Laboratory project.

j. examined the status and potential of lifting body technology, recoverable and re-useable boosters, maneuverable logistic vehicles, and generally encouraged a closer marriage of aeronautics and astronautics.

k. contributed to the planning for foreign visits of U.S. astronauts.

l. reviewed the status of meteorological satellite planning.

m. examined the impact of the national space program upon our international relations.

n. gave direct consideration to various proposals for improved cooperation with other nations in various aspects of the space program.

o. visited space installations, examined facilities, and engaged in interagency as well as Government-industry meetings and briefings on new developments in aeronautics, space technology, and space benefits.

p. maintained a current record of U.S. and Soviet space launches, developed comparisons between U.S. and U.S.S.R. space activities, and reviewed space accomplishments and potentials of other nations.

A seedbed of advanced technological competence has been created by means of substantial investments, both public and private, in facilities, in experience, in organizations, in processes, in products, and in accumulated data. Taken together, this becomes one of our greatest national assets, which can be used at various rates and adjusted to other national requirements. Variations in funding for the use of such resources may be necessary from time to time, but such fluctuations should not be considered as a measure of uncertainty as to the essentiality of the space program or a deviation from this Nation's drive for preeminence in space.

The year 1965 was characterized by increased space activities at home and abroad, improved reliability in space equipment and space performance, and increased public awareness of the permanence and beneficial nature of the national space program. Coordination between U. S. Government agencies improved, and cooperation with other countries became a more characteristic element of space planning. While the actual and potential benefits of the space program are many, uppermost is the strong force which a viable space program can apply in the direction of world peace, as space activities become constructive substitutes for exploitation of peoples and aggression against peoples.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CHAPTER III

INTRODUCTION

The year of 1965 was a period of significant operational accomplishments for the National Aeronautics and Space Administration.

In the GEMINI program, five successful trips furthered manned space flight competence and revealed project flexibility to adjust to unforeseen events. The GEMINI achievements portended adherence to the "in this decade" lunar schedule.

The space science and applications programs also moved forward as two RANGER spacecraft sent back highly detailed pictures of the moon's surface, MARINER IV supplied a series of clear photographs of Mars; and the development phase of the large observatory series of spacecraft neared completion.

Advanced research and technology programs continued to develop basic knowledge supporting aeronautics and space research. The three X-15 research airplanes collected additional data on manned maneuverable flight at hypersonic speeds, arrangements were completed for NASA to use the XB-70 in its research for the supersonic transport, and three PEGASUS satellites launched this year furnished new information on the meteoroid hazard to spacecraft. Progress was also made in nuclear systems research. This included ground tests of an electric power generator using a nuclear reactor and the successful completion of three NERVA reactor experiments.

Another milestone was reached with the firing of the world's largest solid propellant rocket motor when 3.5 million pounds of thrust was attained from the 260-inch motor.

Other NASA programs continued to support Agency progress in these major areas.

MANNED SPACE FLIGHT

The past year was one of increased activity in all areas of the manned space flight effort. The accelerated GEMINI program of two-man earth orbital missions brought the United States to new levels of operational capability. During 1965, five GEMINI manned flights were accomplished with notable success; these followed the second unmanned qualification flight.

Key milestones in the APOLLO program of research and development were reached in spacecraft and launch vehicle ground testing. Extensive facilities were completed or in progress for development of space hardware and for the increased requirements of APOLLO space flight launch operations and mission control. The SATURN I vehicle program was completed in 1965 with a perfect record of 10 successful flights in 10 launch attempts. The APOLLO-SATURN IB was nearing the flight phase following final checkout of the two-stage SATURN IB launch vehicle and the APOLLO spacecraft at Kennedy Space Center. The first flight of the APOLLO-SATURN IB space vehicle is scheduled for early 1966. Training of astronauts for future missions continued and five selectees entered training as scientist-astronauts.

GEMINI Program

Following final qualification of the GEMINI system early in 1965, five successful manned flights advanced this country's capability in space to new levels as specific mission objectives were accomplished. Major objectives of the program are physiological and operational experience in long duration flight, development of the capability to rendezvous and dock in space, experience in astronaut extravehicular activity during orbital flight, controlled re-entry from orbit, and the conduct of scientific experiments.

Management of the program was highlighted by two major accomplishments. The first of these was an acceleration of the scheduled launches, enabling the program to recover from earlier delays in the launch schedule. The second was the conversion of the entire GEMINI spacecraft and launch vehicle procurement to incentive contracts which, while contributing to the acceleration of program schedules and strengthening control of program costs, maintained the high level of GEMINI performance.

The flight and mission support capabilities achieved through GEMINI successes provided a foundation for the upcoming three-man APOLLO flight operations. GEMINI flights during the year began with the second and final unmanned mission (GEMINI II) to qualify all elements of the GEMINI system.

The first manned flight (GEMINI III) served as a successful flight test of the manned system. A new level of spacecraft control was demonstrated during the three-orbit flight as the GEMINI command pilot executed two orbital path changes and the first change of orbital plane by a manned spacecraft.

The second manned flight (GEMINI IV) demonstrated that man can undergo prolonged exposure to weightlessness and safely endure the stress of re-entry following extended space flight. The four-day mission also demonstrated the operational capability of the crew and the spacecraft systems in flights of this duration.

A secondary objective was successfully accomplished during the GEMINI IV mission as one of the Astronauts maneuvered in space outside the spacecraft for 23 minutes of extra-vehicular activity (EVA), making the first use of a hand-held propulsion unit.

The next GEMINI flight (GEMINI V), the second of the three scheduled long duration flights in the program, further extended United States mastery of the space environment. During the eight-day earth orbital flight the spacecraft traveled more than 3 million miles in 120 revolutions of the earth, assuring that man can perform effectively on a flight lasting as long as a round trip to the moon. The duration of the GEMINI V, 190 hours and 55 minutes, exeeded the former record by more than 71 hours.

The eight-day mission also was a milestone in spacecraft performance. The spacecraft systems functioned highly satisfactorily during the flight, including the primary electrical power source, the fuel cell, used for the first time instead of batteries. The fuel cell operated successfully despite abnormal performance of its oxygen supply system. Pressure loss in the oxygen supply feeding the fuel cell caused concern early in the flight and led to temporary modification of the flight plan.

The principal modification was cancellation of the attempt to rendezvous with a radar evaluation pod which had been ejected previously from the orbiting spacecraft. Subsequently in the flight, GEMINI V proceeded as originally planned when it became evident that the oxygen pressure loss did not affect the fuel cell, other than to require operation at reduced electrical power until oxygen pressure increased and stabilized. The importance of man as an integral spacecraft system was clearly demonstrated by the judgment and actions of the crew in shutting down selected subsystems and equipment for various periods of time to reduce power requirements to the fuel cell until the oxygen supply had stabilized enough to allow normal operation of the fuel cell.

Fifteen experiments were successfully performed, including a number of visual sightings, test of the spacecraft rendezvous radar with a radar evaluation pod on the ground at Cape Kennedy, and successful performance of a simulated rendezvous. The simulation required four precise maneuvers of the spacecraft in which command pilot Cooper changed its apogee, perigee, and orbital plane in order to intercept a simulated target.

The accelerated schedule of GEMINI launches during 1965 maintained by GEMINI II, III, IV, and V was temporarily interrupted by cancellation of the GEMINI VI rendezvous and docking flight as originally planned. The flight plan called for GEMINI VI to fly to and link up with a separately launched, unmanned Air Force AGENA target vehicle, modified to meet NASA requirements.

After normal launching by an ATLAS launch vehicle, the AGENA failed to function properly. Communication with it was lost shortly after successful stage separation, and radar tracking indicated that the vehicle broke up in flight. Launch of the GEMINI spacecraft was therefore postponed.

The Air Force Space Systems Division investigated the incident and reported that the most probable cause of failure was a hard start of the AGENA'S primary propulsion system. With another modified AGENA unavailable for a rendezvous and docking mission until early 1966, the long duration GEMINI VII mission originally scheduled for the first quarter of 1966 was moved up into 1965 and the flight of GEMINI VI was rescheduled to take place during part of the two-week GEMINI VII flight. This rescheduling led to the accomplishment of rendezvous between two manned spacecraft in 1965.

GEMINI VII demonstrated manned orbital flight for a period of 14 days. This mission, primarily a long duration medical mission, consisted of 20 experiments and numerous operational activities. Nineteen of the 20 experiments were successful. In addition, the astronauts removed their pressure suits to allow an evaluation to be made of comparative freedom of operation and personal comfort. Preliminary medical evaluation and data analysis indicated that there were no detrimental effects from exposing the crew to long periods of weightlessness.

GEMINI VI and GEMINI VII could accomplish rendezvous because the spacecraft and launch vehicle for GEMINI VI had been completely checked out and required a minimum of rechecking. GEMINI VI was erected on the pad and prepared for launch. The launch was attempted eight days after GEMINI VII but was aborted because of minor problems. The problems were resolved, checkout was completed, and the launch was carried out three days later.

The rendezvous of the two spacecraft occurred five hours and 41 minutes after launch, during the fourth revolution of GEMINI VI. The two crews flew in formation for nearly five hours, under both night and day conditions, performing numerous maneuvers and taking photographs of each other's spacecraft and thruster plumes. GEMINI VI maneuvered to within about one foot of the GEMINI VII spacecraft, and the astronauts reported that they could clearly see the facial expressions of the GEMINI VII crew. Following completion of the rendezvous activities, GEMINI VI separated to a distance of approximately thirty miles for the rest period. GEMINI VI performed three experiments in addition to the rendezvous activities.

The GEMINI VI and GEMINI VII spacecraft both executed controlled re-entries, with GEMINI VI landing less than 7 nautical miles from the planned launching point, and the GEMINI VII, about 6. 6 nautical miles from its planned landing point. The success of the GEMINI VI and VII missions has verified the operational concept of space rendezvous necessary for the APOLLO lunar mission. The GEMINI VII spacecraft traveled more than five million miles in 206 revolutions of the earth during its 330 hours in space, surpassing the record previously set by GEMINI V.

APOLLO Program

Significant strides were made in the APOLLO Program during 1965. Important gains were made in each of the program elements. It was a year of extensive development and testing of the necessary large launch vehicles and engines, sophisticated spacecraft, and comprehensive ground support equipment.

Key milestones in the APOLLO Program were being met on schedule, and the substantial progress made during 1965 provided a strong basis for confidence that APOLLO program objectives would be successfully fulfilled. These objectives are to build a broad-based manned space flight capability, and to land men on the moon and return them safely to earth within this decade.

The major milestone in the APOLLO schedule for the rest of the decade are as follows: The first unmanned flights of the APOLLO spacecraft, using an intermediate launch vehicle, the SATURN IB, in 1966; manned flights of this spacecraft on the SATURN IB, carrying three men, in 1967; also in 1967, the first unmanned flights of the APOLLO-SATURN V, the vehicle to be used for the actual lunar flights; and manned flights of the APOLLO-SATURN V in 1968.

SATURN I -- On July 30, the tenth and final flight of the SATURN I launch vehicle was successfully conducted at the Kennedy Space Center (KSC). The 1 1/2 million pound thrust SATURN I thereby achieved a perfect record of ten successes in ten launches, a record without parallel in the development of launch vehicles. In its last three flights, which took place during 1965, the SATURN I placed in orbit PEGASUS satellites for the measurement of micrometeoroids in space. Preliminary data from these satellites indicate that the APOLLO spacecraft structure is adequate to resist meteoroid penetration.

The SATURN I program provided the base on which U. S. large launch vehicle technology is built, and its results are being utilized in the preparation of flights of the SATURN IB and the SATURN V launch vehicles. It served as the basis for demonstrating this country's ability to develop and launch large space vehicles, and aided the nation in developing its broad manned space flight capability.

The specific accomplishments of the SATURN I program were many. It played a vital role in developing the first stage of the SATURN IB by verifying the effectiveness of cluster engine techniques and lead the way in the development of cryogenic upper stages using liquid hydrogen as fuel. This fuel will be used in the upper stages of the SATURN IB and the SATURN V. In the SATURN I program, the guidance system was developed for the SATURN IB and the SATURN V.

In addition, direct flight hardware support for the SATURN IB vehicle was achieved by the use of several major first stage components of the SATURN I for the first stage of the SATURN IB. The SATURN I program facilities and hardware enabled NASA to move more quickly and at less cost into the APOLLO-SATURN IB Program.

Phase I of the APOLLO-SATURN launch vehicle flight program, the base upon which the rest is built, was thus completed in 1965.

APOLLO-SATURN IB -- During 1965 the flight phase neared in the APOLLO-SATURN IB program, the first of two major portions of the APOLLO program. Objectives of this phase are to develop the second stage of the SATURN IB vehicle, which will also serve as the third stage of the SATURN V; to carry out development of the Block I series of Command and Service Modules (CSM); to carry out the initial development and verification testing of the Lunar Excursion Module (LEM); and to develop and flight test the Block II Command and Service Module with the LEM in manned earth orbital missions of up to 14 days.

Rapid progress was made throughout the year to support the first launch of the APOLLO-SATURN IB space vehicle (AS-201), an unmanned suborbital ballistic flight, now expected to be conducted in the first quarter of 1966. This flight is designed to test the launch vehicle-spacecraft compatibility, and will mark the first time that flight model APOLLO Command Service Modules have been flown.

A major milestone was met in December with the complete activation Launch Complex 34 for the AS-201 flight test. Major modifications were necessary to convert the complex from the SATURN I configuration to accommodate the APOLLO-SATURN IB space vehicle. Similarly, conversion of Launch Complex 37B, the other APOLLO-SATURN IB launch facility, was begun in 1965.

Also in December, the AS-201 spacecraft and launch vehicle were mated on Pad 34, and pre-flight checkout was proceeding at year's end.

Significant milestones were achieved in the SATURN IB launch vehicle program during the year.

Formal qualifications of the first-stage engine, uprated in thrust from 188,000 to 200,000 pounds, was accomplished in April, and the first static test of a flight vehicle using the 200,000-pound-thrust second stage engine was successfully completed.

The concept of the successful SATURN I Instrument Unit has been basically retained for the SATURN IB and SATURN V Instruments Units. Most of the Ground Development and Qualification Test Program was successfully completed.

The first and second stages of the launch vehicle for the second APOLLO-SATURN IB mission (AS-202) were static-fired during 1965 and were scheduled to be delivered to Kennedy Space Center in early 1966. The weight SATURN IB could place in earth orbit was increased to 40,000 pounds, an increase of 5,000 pounds.

Flight test and qualification of the APOLLO launch escape system (LES) under various abort conditions continued during 1965 at the White Sands Test Facility (WSTF). Other objectives of the program are to develop and flight test the parachute recovery system, the earth landing system, and to carry out structural tests of the spacecraft.

In a flight test in May, designed to test the LES in a high altitude abort, the LITTLE JOE II launch vehicle developed a high spin during early powered flight and eventually disintegrated. The launch escape system sensed the vehicle malfunction and separated the spacecraft from the booster without damage. The earth landing system performed successfully under the unexpected and unusual circumstances, and the Command Module made a safe landing. Although the high altitude abort objectives were not met, it will not be necessary to repeat the test, since sufficient data is expected to be gained from the intermediate abort flight in early 1966 to meet the unfulfilled objectives of the earlier flight.

In February 1965 critical propulsion tests of the Service Module engines began at WSTF in New Mexico and continued throughout the year. Testing included system checkout runs; many engine starts, restarts, and shutdowns; and runs with varied engine mixture ratio, high and low chamber pressure, propellants conditioned hot or cold, and with the Service Module engine being gimballed. These are the engines that will enable the astronauts to make mid-course corrections on their way to and from the moon.

In April, delivery was completed of the APOLLO boilerplate spacecraft for the comprehensive test program, and important spacecraft (airframe) structural tests were initiated in May.

All development and essential ground qualification testing on the early model Block I Command Module Guidance and Navigation Systems was completed.

In the area of Command and Service Module checkout, Ground Support Equipment (GSE) designs and test plans were verified, checkout procedures and associated hardware were corrected and refined, computer checkout programs and testing techniques were developed, the necessary equipment was procured, and all factory and KSC test sites for checkout of the first spacecraft were activated.

At year's end, the spacecraft for the first manned APOLLO-SATURN IB flight was in the final stages of systems installation at the factory, and the spacecraft for the second manned flight was also undergoing systems installation.

<u>APOLLO-SATURN V</u> -- The objectives of the APOLLO-SATURN V program are to develop the SATURN V launch vehicle and to complete the development and verification of the Block II Command and Service Modules and the Lunar Excursion Module, in preparation for the beginning of the manned exploration of the moon within this

decade. The SATURN V will be capable of placing 285,000 pounds into earth orbit, and of sending 95,000 pounds to the moon.

During the year, all three stages of the SATURN V launch vehicle were test fired for full duration runs.

A major milestone in the APOLLO-SATURN V Program and in rocket technology was accomplished in April with the successful test firing of the first stage of the SATURN V. The full 7 1/2 million pounds of thrust was generated by the cluster of five F-1 engines during the 6 1/2 second test. This is five times the thrust of the basic SATURN I. The firing was accomplished almost three months ahead of schedule.

Later in the year, the first stage successfully underwent its first full duration test for a period of 2 1/2 minutes in August. The one million pound thrust second stage was also successfully test fired for its full duration of 6 1/2 minutes in August; and the 200,000-pound thrust third stage, with its single J-2 engine, was successfully test fired in April for its full duration of 8 1/2 minutes.

The second stage, consisting of five J-2 engines, each generating 200,000 pounds of thrust, is the pacing item in the development of the SATURN V launch vehicle and in the APOLLO-SATURN V Program. Because of its size and its use of liquid hydrogen as fuel, it is probably the most difficult of the stages to build, and some welding and insulation bonding problems were encountered which caused delays of two to five months in delivery schedules. In addition, the structural/dynamic stage failed while undergoing structural tests. Although the test was a success, the stage failed at its ultimate design load and was destroyed. This caused the test program to be rephased. Taken together, these problems placed the second stage in a critical condition in terms of supporting APOLLO objectives.

The second stage did complete a substantial portion of its ground testing in 1965. Successful cluster firings were achieved and the common bulkhead was structurally certified. The common bulkhead separates the liquid oxygen from the liquid hydrogen and is therefore probably the most critical component in the stage. At the end of the year, the first four flight stages of the second stage were in manufacturing.

Rapid progress was made during 1965 in the development of the SATURN V third stage, with its single J-2 engine. This is essentially the same as the second stage of the SATURN IB. Many test firings were completed, in some of which successful stage restart capability was demonstrated. The first four flight stages for the SATURN V were in manufacturing at year's end.

Similar progress was made during 1965 in the development of the APOLLO spacecraft, a versatile three-man vehicle, with an extensive maneuvering capability. It is composed of the Command Module, the Service Module, and the Lunar Excursion Module, or LEM. The Command Module houses the astronauts in flight from earth to an orbit about the moon, and back to earth. The Service Module contains the power supply and the propulsion systems and fuel for maneuvering and making mid-course corrections during the lunar flight. The two-stage Lunar Excursion Module separates from the Command Module in lunar orbit and lowers two of the three astronauts to the surface of the moon. After the initial exploration is completed, it lifts off from the moon and reunites the two lunar explorers with the Command Module, carrying the third astronaut.

In August, fabrication was begun of the first Block II Command and Service Module of the type that will be used for the actual lunar landing missions. These vehicles embody the basic Block I design along with modifications and improvements necessary for the APOLLO lunar mission. The principal modification is the incorporation of the docking structure on top of the Command Module to accommodate docking with the LEM and to permit astronaut passage between the Command Module and the LEM.

Design and development of the lighter Block II Guidance and Navigation system which will be used on both Command and Lunar Excursion Modules for lunar flights, were completed and a number of engineering models underwent extensive ground testing.

The Lunar Excursion Module (LEM) development program follows the Command and Service Module by about one year, with 1965 a year of component development tests. The year 1966 will be a year of major ground tests, and 1967 will see the initial flight tests.

The past year was one of progress in the LEM development program and also one in which the program was significantly realigned. During 1965, the major development effort on components was essentially completed, but subsystem development testing was behind schedule at year's end. This created delays in ground test articles and flight vehicles, together with a weight increase that caused considerable concern.

Following a thorough review of these problems, a realignment of the program deleted certain hardware items and reduced the amount of testing on others. A program was initiated to reduce the weight of the hardware.

During 1965, the LEM ascent and descent engines were subjected to considerable testing. A major milestone was reached with the first firing of the ascent engine in a propulsion test rig at WSTF.

The environmental test program at Arnold Engineering Development Center (AEDC) in Tennessee was started. Several firings were made in this phase and a few design deficiencies were discovered and corrected. At year's end, preparations were almost completed at White Sands to start altitude firing of the engine to prove engine-vehicle compatibility.

Considerable testing of the LEM descent engine was accomplished at both sea level and altitude. In addition, a number of environmental firings were made at the Arnold Center. A descent engine propulsion rig was delivered to White Sands and initial testing was started on this system.

The first two LEM Test Articles were delivered; these are to be used in the development program to verify subsystem and vehicle operational and performance requirements. Manufacturing was completed on one other, and the remaining three were in fabrication and assembly, and will be completed in 1966. At year's end, the first three LEM flight vehicles were in fabrication and assembly, about four months behind schedule.

APOLLO Applications

The definition of the APOLLO Applications Program was begun in 1965. The overall role of this program is to provide a foundation for defining and understanding a follow-on major step in space. This goal will be achieved through a series of flight missions designed to acquire scientific, technological, and operational data and experience in earth orbit, in lunar orbit, and on the lunar surface.

The three broad objectives of the APOLLO Applications program are: to develop operational equipment and techniques; to obtain direct benefits to man; and to conduct further scientific exploration of space.

The first objective, development of operational equipment and techniques, is a prerequisite to man's continuing exploration and utilization of the space environment, and to NASA's further support of the Department of Defense. It may lead to future earth-orbiting manned space stations, manned lunar observatories, manned exploration of the near planets, or some combination of all three.

The APOLLO Applications Program, using the APOLLO-SATURN systems, can further remove barriers to man's ability to conduct manned activities in synchronous orbit and to transfer materials in space, with applicability to space refueling or space rescue activities. Other operations are the orbital assembly of large, complex structures, manned orbital flights of up to four months duration by rendezvous resupply, land landing of manned spacecraft returning from orbit, and manned lunar surface operations of up to two weeks' duration.

The second objective, direct benefits to man, can be attained from missions in earth synchronous orbit and on extended space exploration. From earth-synchronous orbits, manned observations may be made of weather patterns and the influence of extraterrestrial phenomena on such patterns. This knowledge will lead to more accurate, long-range weather predictions and, possibly, to weather control techniques.

Another benefit to be gained from earth orbit is synoptic data on the worldwide status of natural resources. This data can reveal new information of value as to mineral deposits, water resources, crops and forests, geological and oceanographic phenomena, the utilization of the earth's resources, earthquake prediction, and other earth phenomena.

The third objective, scientific exploration of space, would include the exploration of the moon. Exploration would also allow the acquisition of astronomical data on the sun, planets and stars which can far exceed the quality and quantity of such data achievable from earth-based or unmanned orbiting observatories.

In testing and demonstrating man's ability to accomplish national space goals, APOLLO Applications is expected to produce results applicable to the unmanned, intermittently manned, or continuously manned space systems that the nation will be able to operate in the years after 1970.

Experience and knowledge gained in this program will provide the basis for capabilities during the 1970's and 1980's for space stations in earth orbit, for lunar observatories, and for manned planetary explorations.

Advanced Manned Missions

In the area of advanced manned missions, NASA continued its studies of future programs needed to carry out manned space flight objectives in the national interest. These studies were directed toward operations in earth orbit, lunar orbit, on the lunar surface, and in deep space; they were being carried out in two distinct phases.

The first of these, aimed at exploiting manned space flight capabilities of the APOLLO program, considered potential missions which would make use of the GEMINI and APOLLO operational techniques and of the basic APOLLO hardware -- the APOLLO spacecraft and the SATURN IB and V launch vehicles. These studies of APOLLO applications reached the point of project definition midway in the year.

The second and continuing study category of advanced manned missions considered potential missions requiring the development of new operational capability and advanced space vehicles. This broad group of studies comprises potential missions for extended lunar exploration, extended earth orbit missions using space stations, and deep space exploration. A comprehensive experiment program covering scientific, technological and earth-beneficial objectives is being developed for both APOLLO Applications and Advanced Manned Missions. Studies also were conducted on the future launch vehicles required for such missions.

SCIENTIFIC INVESTIGATIONS IN SPACE

During 1965 NASA made substantial advances in its various space science and applications programs. Among noteworthy accomplishments were the RANGER spacecraft high-resolution pictures of the moon's surface and the MARINER IV photographs of Mars. The Agency also launched its first satellite designed primarily for geodetic investigations. In meteorology, weather data collected by TIROS was relayed from the U.S. to France by EARLY BIRD -- the first commercial communications satellite launched by NASA for the Communications Satellite Corporation.

Bioscientists ushered in a new era of systematic investigations of the effects of the space environment on living matter when the Astronauts aboard GEMINI III activated two basic biological experiments. And the Agency prepared to launch its first BIOSATELLITE -- a recoverable orbiting biological laboratory designed to study the effects of radiation, weightlessness, and other stresses of space on plants, animals, and other life forms.

FLIGHT PROGRAMS

Emphasizing the growing importance of large unmanned spacecraft for scientific studies in space, NASA orbited two observatories during the year, and launched several geophysical satellites in its EXPLORER series. Sounding rockets were used in increasing numbers for atmospheric research and airplanes provided scientists with flying laboratories to observe a solar eclipse in the south Pacific and the Ikeya-Seki comet.

Second Orbiting Solar Observatory

OSO-II, the second Orbiting Solar Observatory, was launched on February 3 to continue observations begun by the first Orbiting Solar Observatory (OSO-I) in 1962. The satellite was designed to make detailed measurements of ultraviolet, and x- and gamma ray radiations of solar energy and study the sun's corona and the zodiacal light. A more advanced observatory than OSO-I, it is able to scan across the solar disk and can point toward the sun's center with greater accuracy.

After several weeks in orbit, the experiments on the pointing section ceased functioning. Late in November communications from the satellite were turned off after

OSO-II had exceeded its operational life expectancy by fifty percent and had depleted the gas supply needed for pitch stabilization. A third OSO failed to achieve orbit on August 25 when a launch vehicle failed.

Second Orbiting Geophysical Observatory

OGO-II, an Orbiting Geophysical Observatory, was placed into a low polar orbit on October 14. Unlike the first Orbiting Geophysical Observatory (OGO-I) which reached an altitude of 92,000 miles, OGO-II orbits between 250 and 940 miles to enable it to make observations relatively close to the earth. Although difficulties in the launch made its apogee higher than planned, this polar orbit permits observations over practically the entire earth daily. The satellite's 20 experiments were carefully coordinated to act as a single experiment involving the upper atmosphere and ionosphere, the magnetic field, the radiation belts, cosmic rays, micrometeorites, and solar emissions. Initially stabilized as planned, later OGO--II's horizon sensors locked at times on high cold clouds instead of on the earth's horizon. By late October its supply of control gas was depleted and the satellite lost stabilization and began tumbling. After that its power supply has varied and data from its experiments were acquired when power was available.

Other Geophysical Satellites

NASA's first satellite devoted primarily to geodetic studies, EXPLORER XXVII was launched April 29 to chart irregularities in the gravitational field of the earth. A secondary experiment of EXPLORER XXVII (the principal mission for EXPLORER XXII orbited in October 1964) is to make a worldwide survey of the atmosphere's electron content. This survey involves 86 ground stations in 36 countries and is limited to latitudes below 41 degrees. The satellite carries another experiment in laser tracking to continue studies with lasers begun with EXPLORER XXII.

EXPLORER XXVIII was orbited May 29 as the third Interplanetary Monitoring Platform (IMP). This EXPLORER ranges from 120 to 164,000 miles from the earth to gather data on interplanetary magnetic fields and study charged particles coming from the sun and elsewhere in the solar system. Such information will help pinpoint radiation hazards for astronauts in space, as bioscientists study methods of counteracting these radiation exposures.

EXPLORER XXIX -- NASA's first satellite devoted entirely to geodetic studies -- was launched on November 6 as part of a coordinated U. S. Geodetic Satellite Program involving the Agency and the Departments of Defense and Commerce. The program is one of broad international cooperation in ground-based observations and data acquisition and analysis through integrated world-wide networks. The five systems of instruments carried by the satellite were designed to meet the needs for more precise data to be used in mapping long distances and an analyzing geophysical problems. EXPLORER XXIX is gravity-gradient stabilized to keep one face pointing toward the earth.

A Solar Radiation Satellite (EXPLORER XXX) developed by the Naval Research Laboratory was launched on November 19 to continue solar studies of the Laboratory's scientists.

ALOUETTE II, a second satellite built by Canada to continue topside ionospheric soundings begun by its ALOUETTE I and extend them to polar regions, and EXPLORER XXXI were placed in close orbits by a single launch vehicle on November 28. The EXPLORER satellite carries eight experiments correlated with the five of ALOUETTE II. The spacecraft will make related studies of the ionosphere as they orbit close together.

A French-built satellite, FR-I, was orbited on December 6 by a SCOUT vehicle. Although the first launched in the French-American cooperative program, it was the second French satellite.

Also moving toward an expected early launch in 1966 was the Orbiting Astronomical Observatory (OAO).

RANGER Series

The RANGER lunar photographic missions, begun August 23, 1961, were concluded with the launchings of the eighth and ninth in the series on February 17 and March 21. The last three RANGER spacecraft provided over 17,000 high-resolution pictures of the moon's surface to pave the way for the next unmanned lunar programs (SURVEYOR and LUNAR ORBITER) and indicated that some areas were smooth enough for astronauts to land on them.

RANGER VIII took more than 7,100 photographs before it impacted in the southern portion of Mare Tranquillitatis. RANGER IX photographed features as small as 13 inches on the floor of the crater Alphonsus. Its crash landing -- after taking 5,814 pictures -- was televised live for millions of viewers.

NASA has sent data supplied by the Ranger flights to scientists here and abroad for their studies which promise to lead to a better understanding of the solar system.

MARINER Mars Flyby

On July 14 MARINER IV flew by Mars and supplied 21 remarkably clear photographs of the planet and other data revealing that it has a heavily-cratered surface like the moon's, with no evidence of volcanic activity nor erosion caused by water. Also data transmitted failed to supply any evidence of a dust belt, magnetic field, or radiation belts as are found around the earth. Radio signals sent when the spacecraft passed behind Mars showed that the planet's atmosphere was extremely thin -- a vital discovery in planning unmanned and manned landings. The Martian environment emerged as one more unlike our own than was expected. Left to be answered by future missions, was the question of the existence of life.

MARINER IV on October 1 set a new record by communicating from over 191 million miles away -- greater than twice the distance from the earth to the sun. In more than 307 days of operation it transmitted 46 million engineering and scientific measurements, and found the environment between the earth and Mars (except for reduced solar activity) not too different from that of the space between the earth and Venus as discovered by MARINER II in 1962.

The spacecraft continues to orbit the sun. Data may be received from it again when it reaches a minimum distance of 29 million miles from the earth during 1967.

SURVEYOR

Development and testing of the SURVEYOR spacecraft to soft land a payload on the moon continued during 1965. The first flight spacecraft was subjected to extensive functional and environmental tests. Also special vehicles tested major subsystems and the fabrication and testing of hardware for more advanced SURVEYORS were underway.

LUNAR ORBITER

Initial launching of a LUNAR ORBITER spacecraft was scheduled for 1966. The nation's first satellite of the moon, the spacecraft will photograph large areas of lunar surface to obtain topographic information needed for selecting landing sites. LUNAR ORBITER will also make environmental measurements of the moon and obtain data on its gravity field.

In 1965 the design of all elements of the spacecraft was completed as was flight acceptance testing for its major components. A prototype was tested to verify overall systems design, and assembly of the spacecraft for use in flight missions was begun.

Plans for the first mission were completed and sites to be photographed on the mission selected. The necessary computer programs were also completed and their integration commenced. Planning for processing and analyzing photographic and tracking data supplied on each mission was underway.

PIONEER

The first of four PIONEER spacecraft was launched on December 16. The 140-pound spinning spacecraft should transmit data on interplanetary space when it is as far away from the earth as 50 million miles. It will be able to measure magnetic fields, solar plasma, energetic particles, and electron density.

A second PIONEER was being assembled for a launch in mid-1966. The trajectory of this spacecraft should carry it behind the earth and more than 20 million miles farther from the sun than the earth. Scientific payloads for the third and fourth in the PIONEER series were selected. They will include a cosmic dust detector, as well as experiments in magnetic fields and energetic particles. The series may provide a continuity in exploring interplanetary phenomena for the first time as solar activity moves toward its peak.

VOYAGER

NASA currently plans for unmanned VOYAGER spacecraft to orbit Mars during 1973 when the Red Planet is relatively close to the earth. During 1965 the Jet Propulsion Laboratory was assigned the responsibility of managing the VOYAGER Project and the management of the spacecraft, capsule and mission operations systems. The Marshall Space Flight Center will manage the launch vehicle system; NASA's Office of Space Science and Applications is responsible for the VOYAGER Program.

Three contractors were selected for preliminary design studies of the spacecraft system. And in-house studies of the capsule system were conducted to define various modes and conceptual designs. Plans now call for SATURN V to be used in a 1973 launch, with two spacecraft to be launched by a single SATURN V. VOYAGER will obtain data on the existence of extraterrestrial life on Mars and supply information on atmospheric and surface characteristics of the planet, and on the planetary environment.

BIOSCIENCE PROGRAMS

Biosatellites

NASA plans to launch its first BIOSATELLITE late in 1966. During the past year experiments for these orbiting biological laboratories in the flight hardware stage were being tested under simulated flight conditions. Designed to pinpoint hazards for astronauts during prolonged trips in space, these experiments involve various plants, animals, and other life forms to be orbited by Thrust-augmented DELTA rockets for periods of three days to a month.

Environmental Biology

An X-ray bone densitometry method was tested by volunteer patients during 15-and 30-day bed rest studies to determine losses of calcium from the skeleton. Skeletal calcium losses of astronauts during weightlessness in the June and August GEMINI flights were determined by this method and it will be used in future GEMINI and APOLLO missions and in the BIOSATELLITE primate experiment.

Exobiology

Using a simulated primitive earth atmosphere NASA's bioscientists synthesized five nucleosides -- the chemical building blocks of living cells. The nucleosides were prepared in "good yield" under non-biological conditions as they might have existed on the primitive earth. This synthesis scientists believe retraces a critical phase in the chemical evolution of living matter and represents a major advance in explaining the origin of life, a key in detecting extraterrestiral life forms.

Spacecraft Sterilization

Research on sterilizing spacecraft for trips to the moon has shown that they may be decontaminated by holding them in clean rooms for the last 20 days before launch. Biological contamination of spacecraft to land on Mars may be reduced by ultraclean manufacture and assembly, sterilization with dry heat, and by protecting them from recontamination during launch and exit from earth's atmosphere.

The improved methods resulting from this research will find practical applications in surgery and the protection of hospital patients, pharmaceutical and food preparation, tissue culture, and cancer research.

Manned Space Science

Space science investigations included on the two-man GEMINI flights have helped scientists find out how well man can work when away from the earth's atmosphere. Although there was little room aboard these spacecraft for experiments, the success of the 14 valuable investigations orbited during the first 4 manned flights marked a milestone in the GEMINI program. This experience proved that a man could perform efficiently in space at the same time that techniques of flying a new spacecraft system were being perfected.

Photographs taken in orbit by Project GEMINI astronauts supplied invaluable data on airglow, auroras, zodiacal light, and other celestial phenomena. Their synoptic terrain photography revealed certain geological features of parts of North America, Mexico, and Africa previously unrecognized and led to requests from oceanographers for additional photographs of oceanographic features during future flights. Synoptic weather photography provided pictures covering a broad range of meteorological phenomena which were being analyzed to obtain information on various cloud systems.

Space science and applications investigations were selected and assigned to be carried out on early APOLLO earth-orbital and lunar missions. Geophysical measuring equipment to be left on the lunar surface by APOLLO astronauts was also being developed.

SATELLITE APPLICATIONS PROGRAM

Meteorological Systems

TIROS -- Launched in January, TIROS IX successfully introduced a cartwheel design. The spacecraft's cameras, looking out through its side rather than through its base, provided earth-oriented pictures throughout the sunlit portion of each orbit. This is the basic design for the Weather Bureau's TIROS Operational Satellites (TOS) which will provide global and local pictures daily for operational use. TOS satellites are under development, with a first launching scheduled for early in 1966. TIROS X, orbited in July, provided hurricane coverage during the second half of the year.

TIROS VII set new records for longevity, having provided over 100,000 useable pictures in 28 months of operation. It continued to transmit useful data. TIROS satellites have supplied about half a million pictures and identified and tracked 30 hurricanes and 93 typhoons.

NIMBUS -- NIMBUS C (the second NIMBUS spacecraft) was being prepared for a launch early in 1966. The satellite will carry an Automatic Picture Transmission System, an Advanced Vidicon Camera System, and a High Resolution Infrared Radiometer (HRIR) to augment data obtained from the NIMBUS I flight. In addition, the HRIR will provide local nighttime cloud cover to certain ground stations modified to receive these data. Also a Medium Resolution Infrared Radiometer (an improved experiment previously flown on TIROS) will be orbited to continue observing the earth's heat balance.

During the early part of this year development of hardware for the third NIMBUS spacecraft (NIMBUS B) continued and the preliminary design of its flight experiments was completed. NIMBUS B, the basic spacecraft with a number of new sensors, will measure the earth's radiation including the ultraviolet and infrared regions. Data obtained will be used to determine atmospheric temperatures. The satellite will also have a meteorological data collection system to gather information on a global scale. Besides this meteorological data system NIMBUS B will carry a radioisotope thermoelectric generator (SNAP-19) to determine if this highly advanced power source may be used for meteorological satellites.

Meteorological Sounding Rockets -- NASA successfully launched about 150 small meteorological sounding rockets to altitudes of from 20 to 40 miles in developing an inexpensive, self-sufficient, reliable rocket system for locations away from large national ranges. New instrumentation and packages, and rocket vehicles which do not present a falling mass hazard were under development.

Fifty large meteorological rockets reaching heights of 60 miles extended exploration of the atmosphere to new regions of the globe. Rockets fired from Pt. Barrow, Alaska, provided data during the Arctic night for the first time. Rockets were also launched from a mobile shipboard facility off the west coast of South America near the Equator, as well as from several other locations as far as sixty degrees south. Four different experiments were carried into the upper atmosphere -- acoustic grenade firings, sodium releases, pitot-static tube measurements, and radar tracking of inflatable spheres released from the rocket payload.

Communications Satellite Systems

First Commercial Communications Satellite -- EARLY BIRD I, the world's first commercial communications satellite, was launched by NASA in April for the Communications Satellite Corporation. After successful preliminary tests the spacecraft was placed in commercial service in June.

SYNCOM -- NASA completed its basic experimental program with SYNCOM II and III early in 1965 and transferred operation and use of the satellites to the Department of Defense the first of April. SYNCOM II, launched in July 1963, continued to operate in space. SYNCOM III, the world's first geostationary satellite orbited in August 1964, also continued to function successfully.

RELAY -- RELAY II has operated satisfactorily since its launching two years ago. The last remaining U.S. ground station for experimenting with RELAY was taken out of service for modification in September. Future communications experiments with this satellite will be conducted by foreign ground stations only.

RELAY I ceased operating in February after 25 months of service.

TELSTAR -- Ground stations used in experiments with TELSTAR II were converted for commercial service with the EARLY BIRD satellite. A few communications experiments with this TELSTAR (launched in May 1963) were conducted in 1965.

ECHO -- ECHO I and II, NASA's passive communications satellites, still orbit the earth. ECHO I is more than five years old and the second ECHO has orbited for 23 months. These spheres are occasionally studied by scientists but basic communications experiments with them were completed. First generation experimental communications satellites, they have functioned well far beyond original estimates of their lifetime and helped pave the way for operational satellite systems.

Applications Technology Satellites (ATS) -- NASA completed structural models and began final assembly of the prototype model of the spin-stabilized version of the ATS satellites. Expected launch date for the first of these large spacecraft to conduct experiments on several useful applications is late 1966.

LIGHT AND MEDIUM LAUNCH VEHICLES

During the year ATLAS-CENTAUR, SCOUT, THOR-DELTA, ATLAS-AGENA and THOR-AGENA launch vehicles were used for NASA's unmanned missions.

Three ATLAS-CENTAUR vehicles were launched and two others were scheduled for development test flights in 1966.

The fourth development vehicle, launched December 11, 1964, achieved all of its primary test objectives, but a secondary objective of restarting the CENTAUR engines was not fully realized. A fifth development flight on March 2, 1965 resulted in the destruction of the vehicle after two seconds of flight when a valve failed in the booster fuel supply line causing loss of thrust. All test objectives were achieved in the launch of the sixth development vehicle on August 11, 1965.

An ATLAS-CENTAUR vehicle was scheduled to launch the first SURVEYOR spacecraft in 1966.

The four-stage solid-propellant SCOUT launch vehicle orbited EXPLORER XXVII, a geodetic EXPLORER, EXPLORER XXX (a Navy solar experiment), the SECOR satellite for the Department of the Army, and a French satellite, chalking up a record of 12 consecutive successful launches. Completely assembled SCOUT vehicles were successfully transported by air reducing field site and pad occupancy time.

THOR-DELTA vehicles in addition to supporting NASA's space science and applications programs orbited the first commercial communications satellite for the Communications Satellite Corporation and a meteorological satellite for the Weather Bureau. An uprated version of the DELTA vehicle (Improved DELTA) was flown for the first time. DELTA vehicles have successfully achieved orbit in 31 of 34 launches.

ATLAS-AGENA launched the lunar photographers RANGER VIII and RANGER IX, successfully ending this program. Two planetary launches of MARINER spacecraft for flybys of Mars resulted in a success and a failure due to non-separation of a spacecraft's protective shroud. An Orbiting Geophysical Observatory was launched on a Thrust-Augmented THOR-AGENA vehicle and an international satellite for ionospheric studies was orbited by a THOR-AGENA vehicle. Preparations were being made for launches of the Orbiting Astronomical Observatory and Lunar Orbiter in 1966, as well as NIMBUS, PAGEOS, and Orbiting Geophysical Satellites.

ADVANCED RESEARCH AND TECHNOLOGY

The year 1965 saw continuing advances in the acquisition of knowledge to support current aeronautics and space research and to provide a basis for future programs in these areas.

BASIC AND APPLIED RESEARCH

Fluid Physics -- A new theory was developed to describe the mechanism by which water injection into a high temperature ionized plasma reduced the electron concentration associated with the communications blackout problem. Water injection requirements to maintain radio communication for GEMINI and higher velocity reentry conditions can now be predicted.

Research continued on basic chemical kinetics which occur in the combustion and flow processes of propulsion systems. Studies of airbreathing exhaust nozzle flows showed that basic chemical reaction rate data can be applied to predict the recombination and chemical state of the dissociated exhaust gases, and that the fuel specific impulse, calculated from the best information on chemical rates, was close to the maximum value attainable. This indicates that ramjet aircraft range will not be reduced because of inefficient nozzle performance.

Fundamental research in NASA resulted in the experimental proof of one of the most important theories regarding plasma stability. The results are not only significant for space application but also for understanding the mechanism of thermonuclear fusion. The theory predicts an extraordinary damping of the electric oscillations in a plasma, which prevents catastrophic amplitudes.

Applied Mathematics -- Significant progress was made in research on trajectories which will keep the proposed LUNAR ORBITER in any sort of stable periodic motion around the moon. The problem is difficult because the neighboring gravitational fields of both earth and sun are so much more powerful than that of the moon, except within a relatively small space close to the moon. Exact mathematical criteria for periodicity of lunar orbits were established and 111 such orbits were described. A vehicle in one of these orbits would be safe from destruction by the earth's gravitation and could be counted on to revolve around the moon for a relatively long time.

Electrophysics -- Research was conducted to determine whether nuclear magnetic resonance (NMR) technique may reliably detect the presence of water in lunar and planetary rocks and soils. Preliminary results indicate that this nondestructive method may be more sensitive than the standard method although it is not yet certain that it can infallibly and uniquely detect water in the presence of the other chemical constituents of rocks and soil. Investigations of the potentiality of the NMR method are being continued.

Materials -- A new class of stable polymers, called Pyronnes, was synthesized in research to achieve superior spacecraft materials. Pyronnes have unique properties: high resistance to heat and radiation, stability at temperatures over 900°F, and tensile strength which is not degraded by electron irradiation of up to 10,000 million rads. In addition to space applications, Pyronnes may be adaptable to many industrial uses.

Preliminary research indicates that technetium -- a formerly rare element now available in moderate quantities in the wastes from nuclear reactors -- and its alloys have several useful applications. Technetium may have the ability to convert tungsten, a useful but brittle metal, into more pliable form, and several tungsten-technetium alloys are being made in sheet form. Technetium alloys are also among the best of "superconductors," materials which lose all resistance to the flow of electricity when cooled to very low temperatures. Further improvements in superconductivity, if achieved, could advance the development of electric propulsion systems and also drastically reduce the cost of transmitting electrical power.

Studies were in progress to determine why dry metal surfaces wear and seize when they rub against one another (such work could lead to the development of fail-safe or self-lubricating machinery). It was found that the frictional characteristics of dry clean metal surfaces depend upon the pattern and the spacing of the metal atoms (a hexagonal arrangement, for example, allows much freer sliding than a cubic one) and that the change in atomic spacing caused by impurity atoms is also important. Since these arrangements can be changed by alloying and by thermal and mechanical treatments, the means may be available to control dry friction. This would be a valuable advance since oils and other common lubricants may evaporate, decompose, or otherwise degrade in extreme aerospace environments.

NASA is conducting research on materials to protect spacecraft from the meteoroids that will be encountered in varying concentration, size, and speed within the solar system. In experiments at the Langley Research Center, small aluminum projectiles were shot at speeds of 19,000 feet per second into protective bumpers of mylar, magnesium, neoprene, steel, beryllium, and aluminum. For a given kind of space-carft wall, the protection afforded by bumpers made of these materials was found to depend only on the mass per unit area, that is, it was independent of all the other material characteristics. This result is important for the design of spacecraft structures of minimum weight.

AERONAUTICS

Aircraft Aerodynamics

In a continual effort to develop, improve, and simplify analytical techniques for the efficient design of hypersonic aircraft, comparative performance and heat transfer measurements were obtained on a variety of simple wings, bodies, and wing-body combinations of high supersonic and hypersonic speeds. The heat transfer coefficient distributions on the leading edge of delta wings for which the boundary layer remained laminar were in good agreement with laminar swept-cylinder theory for most angles of attack.

Force tests were conducted at Mach 6 on nose-cylinder-flare bodies to determine the effect of nose shape, cylinder length, flare angle, and flare length on the longitudinal aerodynamic characteristics. Results indicated that boundary layer separation effects were significant only with respect to the slope of the normal-force and pitching moment curve at low angles of attack. The variations of the aerodynamic characteristics with the various parameters were, in general, similar to those predicted by Newtonian theory under certain conditions.

Structures -- Wind tunnels studies of the effect of aerodynamic and structural factors in producing panel flutter were correlated with flight data by mounting highly instrumented structural panels on a fighter aircraft and subjecting them to supersonic flight conditions. Also, tests were conducted on simple specimens of various structural materials, such as titanium and aluminum alloys, to establish the fatigue behavior under various environmental conditions, and cyclic loading tests were made on structural box beams representative of current supersonic aircraft structural design.

Air Breathing Propulsion -- Research efforts to improve engine component performance and reduce engine weight continued with special attention to the complex problems associated with the integration of engine-inlet-exhaust system controls. The program on the hydrogen-fueled, supersonic-burning, hypersonic ramjet research engine was in the engine design concept phase. This research engine is expected to advance the technology of air breathing propulsion for hypersonic flight applications such as advanced global transportation systems.

Aircraft Operating Problems -- A three-day NASA Conference on Aircraft Operating Problems held at the Langley Research Center during May was attended by more than 400 technical experts from industry and government. Progress was reported on an air jet technique to improve tire-runway traction, a criterion to define runway roughness including aircraft response, means of controlling aircraft in steep approaches to landing, a way to determine position on the runway during takeoff, laboratory studies of the use of a laser to measure clear air turbulence, the cues required to prevent aircraft from becoming locked in a deep-stall, methods for recovery of an aircraft after upset by turbulence, and the preliminary design concepts for a flight director to permit supersonic transport climb-out operations without exceeding sonic boom restrictions.

NASA continued theoretical and experimental studies of the sonic boom and developed and checked by wind-tunnel and flight tests a new near-field theory useful in predicting the sonic boom characteristics of supersonic transport configurations during transonic climb-out.

Modifications to the NASA variable stability JETSTAR aircraft, permitting it to simulate many different types of aircraft, were completed. As soon as the aircraft completes flight system checks, it will be used to study the proper techniques for flying aircraft in rough air and the potential flight problems of the supersonic transport.

X-15 Research Aircraft

The three X-15 research airplanes continued to provide data on manned, maneuverable flight at hypersonic speeds. As of the end of the year, 156 flights had been made by the three airplanes. During this year, they completed 32 flights, the greatest number of flights in any calendar year. Research programs underway during 1965 for the X-15 included studies of boundary-layer skin friction and noise, horizontal tail loads, ultraviolet stellar photography, micrometeorite collection, aircraft stability and control, Project APOLLO-related horizon scanners and photometers, infrared earth and sky scanners, studies of atmospheric density at high altitudes, a reaction-control automatic stabilization system, and flight tests of various ablation coatings, to find one suitable for the X-15-2 Mach 8 flights scheduled for 1966.

The Fourth Air Force-Navy-NASA Research Airplane Committee Conference on the Progress of the X-15 Research Airplane Program, was held in October. Among the topics discussed were current status and future plans of the program, development of the X-15A-2 aircraft and thermal protection system, heat-transfer, controllability, reentry research, scientific test bed experiments, and hypersonic propulsion system testing.

Supersonic Transport -- In support of the National Supersonic Transport Program, NASA assigned research personnel to the Federal Aviation Agency SST Phase IIC Performance Assessment.

Models of the supersonic transport as conceived by two major aircraft companies were tested in the 40-by 80-foot and Unitary Plan Wind Tunnels. Results of the large-scale low-speed model tests indicated substantial improvement in lift/drag ratio and stability at the stall. Research is continuing on further improvement and refinements to bring these aircraft to the goal specified in the SST program objectives: landing and take-off performance superior to present subsonic jet transports.

Supersonic aerodynamics research included analytical studies to obtain optimum wing twist and camber. New revised analytical computer programs were developed which avoid certain basic theory violations that existed with earlier theoretical programs. The degree of improvement in aerodynamic efficiency of these generalized wing shapes is about eight percent.

V/STOL Aircraft--NASA-sponsored feasibility studies by three aircraft manufacturers were initiated to indicate the specific research work required to develop promising V/STOL concepts into useful aircraft for commercial short-haul transportation. The studies, to be completed early in 1966, emphasize aircraft design aspects, but also take into consideration economic and flight operations influences.

Extensive wind-tunnel studies continued on the aerodynamics of several V/STOL concepts of current interest to the military services, particularly the tilt wing (SC-142A-type), tilt duct (X-22A-type), and lift-cruise fan. Using representative fighter-type models, general research investigations were also made of inlet and exit interference effects, including those resulting in hot gas reingestion. To accelerate such research, a cooperative NASA-Army Materiel Command program was started early this year. Under this program, the Army will provide up to 30 professional and supporting personnel spaces to augment the effort of the NASA staff working in such areas as low-speed aerodynamics and handling qualities of advanced V/STOL aircraft, and will staff and operate a NASA low-speed wind-tunnel facility to satisfy more specific Army research and development needs.

NASA-USAF XB-70 Flight Research Program--In its research for the supersonic transport and for large supersonic aircraft in general, NASA is using the Air Force XB-70 airplane as a unique research facility for increasing knowledge required to achieve safe, efficient, cruise flight with large vehicles at higher supersonic speeds. From the XB-70 it is possible to obtain fundamental research information in aerodynamics, structures and loads, propulsion, and operations under true environmental conditions which cannot be duplicated in any existing or likely future ground facility. NASA installed special research instrumentation in the two XB-70 aircraft and began to acquire research data with the first XB-70 flight in 1964. The flow of data accelerated with the concurrent flight test programs of both airplanes which began in July when the second airplane made its first flight.

A formal NASA-DOD Memorandum of Understanding regarding the NASA portion of the XB-70 program was signed on May 28, 1965. A Management Agreement, implementing the Memorandum of Understanding, was signed by the Air Force and the NASA on October 11. Full NASA participation in the XB-70 program is expected to begin at the end of April 1966.

CHEMICAL PROPULSION

Liquid Propulsion Systems

Since there is no near term requirement for development of a post-SATURN class launch vehicle, work on the M-1 engine program will be terminated following tests of the large-scale components. During the phase-out period, the gas generator, the oxidizer and fuel turbopumps, and the uncooled thrust chamber are being tested on the component level.

Using the results and data obtained in the M-1 engine program together with other experimental tests and technology work, NASA's advanced launch vehicle engine effort will be concentrated upon the toroidal-plug configuration and the high chamber pressure engine. Tests of advanced bell nozzles and toroidal plug exit configurations indicate potential methods of improving overall engine system performance. High pressure hydrogen pump tests were conducted, and a high pressure oxygen pump was designed and fabrication initiated. Further studies and experimental research were continued to correlate combustion instability phenomena and effects. Propulsion technology and experimental work were being extended to provide a sound basis for development of advanced engines utilizing the concepts emerging from the current experimental and research effort.

In the spacecraft propulsion area, the following propellant combinations were being studied: hydrogen-fluorine, hydrogen-oxygen, oxygen difluoride-monomethyl hydrazine, oxygen difluoride-hydrocarbon. Mixtures of fluorine and oxygen (FLOX) can be substituted for oxygen or oxygen difluoride. Each of these combinations was fired, performance and feasibility were demonstrated, and evaluation is being performed in order to develop system concepts, nozzle and chamber cooling capabilities, fluid system design criteria, and handling requirements.

Particular problems associated with fuels or components were being investigated. For the problem of reducing hydrogen "boil off," gellation techniques and sub-cooling of liquid hydrogen are considered promising. To cope with the high reactivity of fluorine and oxygen difluoride, effort was directed to developing adequate design criteria. Also, since the high combustion temperature produced by oxygen difluoride and diborane (about 8000°F) cannot be contained by current flight weight combustion chambers and nozzles, research on high temperature components was continued for a practical design approach which would permit further investigation of oxygen difluoride and diborane and similar high energy propellant combinations.

In the liquid experimental engines work, kinetic losses associated with the nozzle expansion process were measured with the fluorine-hydrogen combination in the low pressure regime where these losses produce significant degradation of specific impulse. Higher pressure pump-fed engine system performance and operating characteristics were demonstrated with fluorine-hydrogen and FLOX-methane using the RL-10 engine (with modifications) as a test bed. Criteria for the design, fabrication, inspection, and servicing of flight weight fluorine feed system components are to be established as one of the objectives of a recently initiated program. In the auxiliary engine area, projects were started using monopropellant hydrazine and high energy LOX-hydrogen propellants.

Solid Propulsion Technology

NASA continued efforts to advance solid technology with studies of such areas as new higher energy propellants, metal combustion processes, instability mechanisms, and two-phase flow problems. Research was conducted on motors capable of command restart and thrust variation in space, on the technology of hybrid systems, and on problems arising from the great size of present and projected solid motors. One such problem--determining the structural integrity of these large solid grains by non-destructive testing techniques--was being actively investigated.

In the large solid propellant motor program, which became a NASA funding and management responsibility in fiscal 1965, a completely successful test firing was made in September of the first 22-foot-diameter, 80-foot-long motor. It contained almost 1-3/4 million pounds of propellant in a single charge and produced peak thrust of 3-1/2 million pounds during its two minutes of burning time--the highest known thrust ever attained by a single rocket motor. Studies indicate that such motors offer the potential of significant reduction in the cost of launching large payloads and in the time required to develop this capability.

In spacecraft applications, propulsion definition studies were in progress to delineate potential areas requiring the use of efficient new high energy solid and hybrid motors.

BIOTECHNOLOGY AND HUMAN RESEARCH

Oxygen Toxicity Research

On extended space missions, problems may arise from long-term exposure to 100 percent oxygen at reduced pressures. At Ames Research Center a study was under way to determine the upper acute threshold level of oxygen pressure which an animal can tolerate. Rats were continuously exposed to 100 percent oxygen at pressures from 4.8 psi to 14.7 psi for periods of time up to 64 days. It was determined that 8.17 psi is the maximum oxygen pressure which a rat (Sprague Dawley Strain) can tolerate. Above this concentration, significant blood, metabolic, and histological changes were observed. Plans call for these experiments to be extended to rabbits, dogs, and primates.

Bioassay Method for Measuring Stress

Ames Research Center conducted research to discover the hormone which stimulates the anterior pituitary gland and releases adrenocorticotrophic hormone (ACTH) which in turn stimulates the adrenal cortex in reaction to stress. A corollary effort determined that vasopressin or a vasopressin-like hormone apparently gives an indication of stress in an animal, and a precise bioassay method for measuring vasopressin in the blood was developed.

Development of a Nephelometer

In the weightless environment of spacecraft, dust particles in the cabin do not settle out but continue to float and in sizes from 0.5 to 10 microns may be a hazard of biological significance. To measure the concentration of such dust particles, a prototype of an instrument, called a nephelometer, was built and successfully tested. A contract was placed for one such instrument, and plans were made to fly it on one of the early manned APOLLO vehicles.

Spray-on Bioelectrodes for EKG

The NASA Flight Research Center developed a spray-on method for applying bio-electrodes to sense EKG and other bio-potentials. These electrodes can be easily and rapidly applied by personnel with limited training, they maintain electrical contact consistently, they do not require shaving of the electrode area, they may be worn for several hours with no discomfort, and they are easily removed by an appropriate solvent. The spray-on electrodes, with their associated signal conditioners and tape recorders, are presently being used in a joint NASA/USAF project to obtain biomedical data on students of the USAF Aerospace Test Pilot School.

Space Bio-Medicine

Regenerative Life Support Systems--NASA's advanced physical-chemical regenerative life support system, designed to operate for up to a year with expendables resupplied at 90-day intervals, was installed in a "boiler plate" space vehicle at the Langley Research Center. Preliminary manned tests were run and tests of extended duration were scheduled. Life support system components under investigation included such advanced items as solid and molten electrolyte oxygen recovery systems and a phase change--membrane water reclamation system.

Development of Hard Suit--A metal space suit which incorporates constant volume joints was being developed. It offers negligible resistance to movements necessary to man's performance in extravehicular tasks, and leakage is less than one-half that of present soft suits which cannot operate over 3.5 psi. The hard suit represents a significant advance in that it provides the astronaut with considerable mobility, both in space and on the lunar surface, and also offers the potential for radiation, micrometeoroid, and thermal protection. Further research was being conducted on thermal control techniques and longer duration life support systems to be incorporated in the suit.

Flight Experiment--An experiment to provide basic physiological information on how the otolith, a part of the body balance system located in the inner ear, functions in the zero gravity environment was approved to be carried on an early APOLLO flight. For this flight experiment, nerve impulse signals from individual nerve fibers of a frog's otolith, which is similar to man's, will be tapped, and the action of the otolith under weightlessness will be measured by recording its nerve impulses. This information will indicate the adaptiveness of the otolith to weightlessness.

Lunar Locomotion--Locomotion on a simulated lunar surface was found to consume approximately one-third less energy than that required on earth. This finding was derived from oxygen consumption measurements made of men walking, running, jumping, and leaping under simulated lunar gravity conditions. The same method can be used to determine logistic support requirements for life support systems and to collect data on the limitations on travel and work on the lunar surface for both shirtsleeve and pressure suited conditions.

SPACE VEHICLE SYSTEMS

Aerothermodynamics

Flight research programs continued to provide information required for manned and unmanned spacecraft designed for reentry into the atmosphere. The second Project FIRE experiment contributed highly accurate data on spacecraft radiative heating during the critical peak heating phase. In NASA's lifting body research program, one of the two vehicles, which are representative of vehicle shapes suitable for reentry at orbital speeds and for conventional landing at subsonic speeds, was delivered (the M-2) and the other (the HL-10) was nearing completion. Both will be used for flight testing of handling qualities and landing characteristics. Research continued on spacecraft recoverable by parachute. Means of providing a lift capability and of allowing the astronaut to steer the parachute were investigated, and several concepts were developed which may result in lateral maneuverability and glide ranges of about 15 to 20 miles after deployment.

Structures

Studies of techniques for attenuating landing impacts of spacecraft led to a highly efficient concept involving cyclic material deformation. Its advantages include simplicity of operation, adjustment ability for various conditions, reusability, and light weight. In research on winds and turbulence affecting the structural design of space vehicles, the radar-balloon system was improved by incorporating conical projections, which optimize the accuracy of wind measurements used in predicting loads on space vehicles. Studies demonstrated the feasibility of using expandable structures as emergency shelters or extended stay modules on planetary surfaces. These structures, which can be compactly stowed and easily erected on the planetary surface, may be equipped with complete life support systems or use those aboard the spacecraft. Structural problems involving viscoelastic materials are found in solid propellant rocket motor grains where the motor is exposed to thermal and handling loads, in highly heated structures such as entry vehicles, and in supersonic transport aircraft. An experimental technique was developed which makes it possible to perform quantitative stress analysis on such materials, and equipment and techniques were being refined so they can be used routinely in engineering analysis and design.

Environmental Factors

In continued research on the meteoroid hazard to spacecraft, three large PEGASUS satellites were launched by SATURN I vehicles this year to count actual penetrations in large area, relatively thick structural skin samples. All these satellites were furnishing significant new data on the meteoroid hazard. The smaller SCOUT-launched EXPLORER XXIII (launched November 6, 1964) has continued to provide excellent statistical data on penetrations of thin materials. Laboratory studies of a meteorite specimen undergoing simulated atmosphere entry heating showed a substantial change in shape and frontal area as a result of the heating. Since these changes would affect the trajectories of meteoroids, deductions as to meteoroid densities made on the basis of such parameters could be in error, and meteor astronomers who deduce meteor properties from ground-based observations may have to revise their conclusions on the basis of these studies.

Research to improve thermal design and thermal-vacuum test procedures included a series of ground tests of a half-scale model of the MARINER Mars vehicle. Test results were compared with the actual thermal performance of the flight hardware; the data from the scale model tests under solar simulation agreed well with those obtained in flight. These results suggest that thermal scale modeling under steady state conditions can be effectively used as a design and testing tool to improve the thermal performance of spacecraft.

<u>Design Criteria</u>--In accord with its aim of insuring flight worthiness of NASA space vehicles by incorporating the latest technical information into design criteria, NASA made five criteria monographs available to potential users in government and industry. Four monographs pertain to structural aspects of design, and one has to do with the solar electromagnetic radiation environment in which space vehicles must operate.

Previous Element Coding

Research on methods of reducing the amount of redundant data transmitted from spacecraft resulted in the development of a technique known as Previous Element Coding. In this system, electronic circuits operate on television pictures coded in digital form so as to transmit only picture elements which differ from previously transmitted elements. A computer processes received information to reconstruct the entire picture by generating the missing picture elements and inserting them in the proper location.

Ferrite Plate Memories

Research on high capacity, radiation resistant, low power memory devices for computer and bulk data storage use in spacecraft produced a laboratory prototype memory composed of thin sheets of platinum conductors and ferrite material. High packing density and relatively low cost were achieved by using batch fabricating methods. Research was continued on batch fabrication of microelectronic logic circuits for driving and sensing the memory.

Solid-State Imaging System

The basic element of a "scanless" TV camera system using a solid-state imaging device instead of an electronic imaging tube was developed. The system employs molecular electronic circuitry to perform the opto-electronic transfer necessary to obtain a video signal output. A camera built on this principle is rugged, light weight, low in power consumption, and ideally suited for space usage since it does not utilize beam scanning.

Communications and Tracking

During entry of a spacecraft into a planetary atmosphere, there is a communications "blackout" due to ionization of the atmosphere enveloping the spacecraft. The GEMINI reentry communications experiment (T-1) was flown on GEMINI III to investigate the feasibility of water injection as a technique for alleviating this problem at earth reentry speeds. During a portion of the water injection period, blackout was successfully eliminated for UHF and C-band at a reentry velocity of 26, 000 feet per second. These results demonstrated that water injection can be used to overcome the communications blackout problem.

Electrostatic Gyro System

Recent progress on the technology development of the electrostatic gyro led to the initiation of a joint effort with the U.S. Air Force Avionics Laboratory to incorporate the gyro in a strapped-down inertial navigation system. The strapped-down electrostatically-suspended gyro system eliminates complex gimbal structures, angle readout devices, and associated servos, making possible a true space reference platform. The gyros, which can be easily replaced in flight, offer still further advantages over conventional gimballed platforms in reliability and maintainability for long duration missions.

Electronic Techniques and Components--This is a new program established to provide the necessary support research to ensure that electronic component technology will be available for future NASA missions. The principal activity in this effort will be at the NASA Electronics Research Center.

Control Systems--Past research efforts emphasized the investigation and development of advanced concepts and components for future applications. Results of these efforts are being applied in the design of the Advanced Orbiting Astronomical Observatory (OAO) star tracker, the development of an all-axis, inertially coupled, gravity gradient stabilization system for the Advanced Technology Satellite (ATS), and development of a brushless DC momentum wheel torquer. Manual control studies resulted in the development of a simple sighting cross for use in spacecraft docking maneuvers. This technique was carefully evaluated and is now being incorporated into the design of the APOLLO-LEM spacecraft configuration.

NUCLEAR SYSTEMS AND SPACE POWER

During the year, NASA continued working to develop electric power generators employing nuclear reactors; the Agency also moved forward with its solar and chemical power and electric rocket engine programs.

Nuclear Power Generation

A 50-watt electrically-heated prototype isotope generator, the SNAP-19 (Systems for Nuclear Auxiliary Power), was extensively tested at Goddard Space Flight Center. Though some performance deficiencies were noted, the required corrective actions were determined, and the changes were being incorporated.

A decision was made to proceed with the design of a 50-watt isotope generator for the APOLLO Lunar Surface Experiment Package (ALSEP), which is to be left behind by the astronauts after the first lunar landing. This power supply, designated the SNAP-27, will enable scientific information to be sent back to earth for about a year after the astronauts' departure.

SNAP-8 is a project for development of a 35KWe electrical nuclear power system for use in advanced space missions. In 1965, the reactor completed a 12,000-hour test program and was undergoing post-test examination. Performance testing of the first generation of power conversion hardware was completed and endurance testing was initiated.

The NASA advanced nuclear power program is concerned principally with three energy conversion concepts: thermionic direct conversion and both the Rankine and Brayton cycle turbogenerator systems. As part of the Brayton cycle work, investigation into the efficiency and performance characteristics of radial and axial flow turbines and compressors and heat exchangers was expanded; aerodynamic efficiencies of small size radial-flow turbines (6-inch diameter and 4.6-inch diameter) and radial-flow compressors (6-inch diameter and 3.2-inch diameter) were obtained. The performance data obtained were, in general, quite encouraging.

The Rankine turbogenerator effort showed considerable progress in several important component areas. "Dry" performance testing of a 200 kilowatt potassium vapor turbine was conducted, and an endurance run (exceeding 700 hours) of the test turbine was completed. This test is continuing with 2,000 hours operation as its goal.

Many of the materials programs began to yield important test data. A 2000°F liquid sodium corrosion loop constructed of an advanced columbium alloy finished a 2,500 hour test as part of one of the materials programs. The objective of this test was evaluation of the loop components for an advanced alloy boiling potassium corrosion loop. The latter loop, now in operation, completed over 1,800 hours of testing. The two phase potassium heat transfer program completed the single tube phase of the boiler and condenser experimental program. The data indicates that once-through boilers and condensers of acceptable weight and size can be constructed, at least from a heat transfer standpoint.

The largest refractory alloy boiling alkali metal test facility in existence began test operation at NASA-Lewis during the year. This facility will be used in evaluating multi-tube stability effects in 2000°F alkali metal boilers.

The thermionic conversion effort was mainly concerned with high temperature nuclear fuel and fuel-diode compatibility investigations. Tests were performed in-pile both at the NASA-Plum Brook Reactor and at an industry test reactor. In addition, out-of-pile testing of fueled and unfueled converters continued. Both in-pile and out-of-pile converter performance and operating life showed improvement, but degradation of performance with time in both test modes remains a problem.

Solar and Chemical Power

Progress toward a better understanding of the reaction kinetics of battery and fuel cell electrodes was realized during the year. Both primary and secondary alkaline batteries are used extensively to supply electric power to launch vehicles and spacecraft; and fuel cell powerplants are programed for use on the GEMINI, APOLLO, and biosatellite space flights.

Further improvements in performance and life were made on the capillary fuel cell. This low temperature system uses a potassium-hydroxide-water electrolyte held in place between two electrodes by a thin asbestos blotter. Water resulting from the reaction of hydrogen and oxygen is taken from the cell by a static moisture removal design using vapor pressure difference as the driving force. The capillary fuel cell has shown excellent progress toward providing the long life (30 - 45 days) and performance needed for manned space flights beyond APOLLO.

A study and design analysis of a 50 Kilowatt photovoltaic solar cell array was completed during 1965. The use of thin silicon solar cells mounted on lightweight, folding array structures shows promise of providing the electric power that would be needed for such advanced missions as large orbiting space stations and unmanned interplanetary probes driven by electric propulsion systems.

Electric Thrustors

In the past year, the NASA program in electric rocket propulsion made considerable progress. As a result of this technology effort, plans were being made to flight test small electric thrustor systems on the initial NASA Application Technology Satellite (ATS). In addition, a long duration ion engine test was voluntarily terminated after 2,600 hours. The success of this test was the first concrete evidence that engine lifetimes of 10,000 hours may be within reach. Studies evaluating the usefulness of such engines for mid-course propulsion were initiated, and system hardware tests begun. Advanced efforts were continued on the three main classes of thrustor--ion, plasma and electrothermal.

NUCLEAR ROCKET PROGRAM

The major emphasis in the Nuclear Rocket Program was on the development of solid-core graphite reactor and engine system technology. As in previous years, this work was supplemented by a broad research program concerned with the development of non-reactor and engine system technology, the investigation of alternate and advanced reactor concepts, and safety.

Progress in developing graphite reactor and engine system technology was marked by the successful completion of three NERVA (Nuclear Engine for Rocket Vehicle Application) reactor experiments (using the same reactor assembly) and the first reactor test under the PHOEBUS advanced graphite reactor program. The reactor used for this experiment was call the PHOEBUS IA. In addition, final preparations were made for conducting the first full-scale development test of an experimental nuclear rocket engine system (NRX/EST) under the NERVA program.

The three NERVA reactor experiments were conducted on April 23, May 20, and May 28, respectively. The reactor used for all three tests, the NRX-A3, was an improved version of the NRX-A2 design tested last year.

In the first two experiments, the NRX-A3 was run through two power cycles totaling approximately 25 minutes of operation. About 16.5 minutes of this time were at full power. Following these experiments, the reactor was again restarted and used to investigate the effects of the liquid hydrogen propellant on reactor control in the low-to-medium power region. By the close of this run, a total of more than 60 minutes of operation had been accumulated. Operation of the NRX-A3 during each of the tests was very good and sound data was obtained.

The PHOEBUS IA experiment, utilizing a KIWI-sized assembly and conducted by the Los Alamos Scientific Laboratory, was completed June 25. This was the first in a series of reactor experiments designed to evaluate, in the KIWI-size reactor, the important elements associated with the development of a larger diameter reactor. The design of the PHOEBUS IA embodied many of the design innovations suggested by the results of earlier KIWI and NERVA reactor tests. During the start to full power and the full power hold (about 10.5 minutes), the PHOEBUS IA operated according to pre-test predictions. During the shutdown from full power, however, the liquid hydrogen supply in the facility was exhausted, resulting in overheating and subsequent reactor damage. This occurrence was not due to a reactor malfunction but rather to the failure of the facility liquid hydrogen Dewar level gauge which had been indicating a higher than actual residual of coolant. The necessary action has been taken to prevent recurrence of this problem.

In the advanced research and technology portion of the nuclear rocket program, work continued on the development of feed systems, nozzles, controls, and other critical components to support the current graphite reactor and engine technology effort; on evaluating how these components would function in the heat and radiation environment of a nuclear rocket engine system; and on examining the operation of a reactor with these components under cold flow engine test conditions.

In addition to the work being conducted on graphite systems, work continued on a modest scale to explore the performance potential of the tungsten fast and thermal reactor concepts. The effort was concentrated primarily on the development of fuel element materials and fabrication processes, with the objective of establishing the feasibility and performance potential of these systems.

In the area of advanced concepts, basic studies and research were continued at a low level on dust bed, liquid core, and gaseous core reactor systems. The primary emphasis was on the fluid flow and heat transfer aspects of these systems.

The most significant activity in the safety program during 1965 was the completion of an experiment known as the KIWI-Transient-Nuclear Test. The purpose of the experiment was to determine, for a graphite nuclear rocket reactor, the accuracy of theoretical techniques developed for predicting the response of a reactor to very large and rapid insertions of reactivity. The experiment demonstrated that even under launch accident conditions entailing a maximized power event, the safety of personnel at the launch site and off-site could readily be assured.

TRACKING AND DATA ACQUISITION

Under the tracking and data acquisition program, NASA showed significant advancements in the capability to support manned and unmanned flight missions. Network facilities and equipment were modified and augmented to meet the requirements of forthcoming programs.

Manned Space Flight Network

The Manned Space Flight Network, used for the first time in March 1965 to support a GEMINI mission, supported all six GEMINI missions during the year. During the GEMINI III mission, the communications satellite, SYNCOM II, was used for the first time, in conjunction with the network, as a link between the remote ship stations and the Mission Control Center. Real-time communications also permitted excellent coverage of the extravehicular activity.

The SATURN and ATLAS-CENTAUR vehicle missions also were supported. In addition to these NASA missions, some stations of the network supported the DOD TITAN III-C development program.

Management of three stations (Kokee Park, Hawaii; Canton Island; and Corpus Christi, Tex.) was transferred to NASA from DOD for support of GEMINI and future manned flights.

While continuing to cover GEMINI missions, the Manned Space Flight Network is being augmented in preparation for APOLLO support. Existing stations are being modified and new facilities are being established which will provide, for support of manned lunar missions, a network consisting of ten fixed land stations with 30-foot antennas, three stations with 85-foot antennas, one transportable station, five instrumented ships, and eight instrumented aircraft.

Necessary agreements were reached for the establishment of new stations, and the pace of station construction activity increased. Major procurements of equipment continued and deliveries of completed units for installation at stations began. Modification of the ships continued on an accelerated basis. Definitive studies of aircraft instrumentation requirements were completed, and a contractor was selected by the Department of Defense to modify eight C-135 aircraft for communications with the APOLLO spacecraft during its injection into the translunar coast trajectory.

A comprehensive agreement concerning land-based tracking, data acquisition, and communications facilities was reached with DOD. This agreement provides for improved planning coordination, single-agency management of support at co-located stations, and other measures to assure efficient utilization of the ground instrumentation facilities of both agencies in support of the national space program.

A determination was made that for lunar missions it would be necessary to improve communications to certain stations and ships through the use of communication satellites. NASA, as an agent for the National Communications System (NCS), is negotiating with the Communications Satellite Corporation for the necessary services. Also during the year, solid-state switching units for the NASA Operational Communications Network (NASCOM) were installed at communications centers in Australia and England to improve circuit capacity and reliability.

Satellite Network

The Satellite Network is composed of the electronic Space Tracking and Data Acquisition Network (STADAN) and the Smithsonian Astrophysical Observatory (SAO) optical camera tracking stations.

Improvements in the Satellite Network were carried forward as planned to meet satellite program requirements. The second 85-foot antenna system at Rosman, N. C., is now operational, as is the 85-foot antenna facility at Canberra, Australia. These antenna systems, together with the Alaska 85-foot antenna facility and the 40-foot medium gain antenna facilities in South America and South Africa, now provide the network with capability for handling the large data requirements of the observatory satellite program.

NASA and the Australian government joined in selecting a site (near Toowoomba, Australia) for a transportable ground station to support the Application Technology Satellite (ATS), and an agency-to-agency agreement was reached.

Work was started to modify the STADAN station at Goldstone, Calif., for ATS support.

An 85-foot antenna facility at Fairbanks, Alaska, constructed by NASA for the U.S. Weather Bureau, became operational and was transferred to that Bureau for meteorological work. A similar facility is being installed at Wallops Island, Va., for support of the Weather Bureau's TIROS Operational Satellite (TOS) project.

The control center complex at the Goddard Space Flight Center was expanded to provide for greater data handling, command, and control capacity. Such capacity is required for the larger observatory satellites that carry a greater number of onboard experiments operating over longer periods in space.

The network was further improved to provide increased accuracy in tracking of highly eccentric orbiting satellites. An additional Range and Range Rate system became operational at the Tananarive, Malagasy, station.

During the year, this network supported a total of 82 flight missions.

Deep Space Network

The Deep Space Network is a highly precise system which provides communications with, and control of, spacecraft orbiting at lunar and planetary distances. It consists of ground tracking stations spaced at intervals of approximately 120° longitude around the world in California, Australia, Spain, and South Africa, and a control center located at the Jet Propulsion Laboratory, Pasadena, Calif.

During the year, the major flight programs supported were RANGER VIII, RANGER IX, the MARINER IV Mars Fly-by mission, and the early phase of the PIONEER A flight mission (scheduled later this year). For the first time, two missions, MARINER IV and RANGER, were supported simultaneously by the network.

Photographs of the lunar surface taken by RANGER IX and televised nationwide in near-real-time were a major accomplishment. Photographs of the Martian surface accomplished by the Mars Fly-by mission were hailed by many as the outstanding scientific achievement made during the year. As the MARINER IV passed by Mars, the occultation experiment, made possible by very precise tracking accuracy, gave the experimenters excellent data for determining the density of the Martian atmosphere. The MARINER was 135 million miles from earth at the time of encounter. After encounter, the Deep Space Network continued to track and acquire data to establish a new communications range record of 191 million miles between network stations and the spacecraft.

The stations in Canberra, Australia, and Madrid, Spain, were operational for the first time in supporting the MARINER IV project. Construction at Mojave, Calif., of the first 210-foot diameter advanced antenna system was completed and final checkout was under way.

UNIVERSITY PROGRAMS

NASA's Sustaining University Program augments the Agency's extramural research efforts and broadens the base of university participation in the national space program. Its major elements are concerned with predoctoral training, special purpose multidisciplinary research, and the construction of research laboratory facilities.

Under the predoctoral program this year, 1,275 students entered training in science and engineering at 142 universities in 50 states, bringing the total number of trainees to 3,132. (The continued aim of the program is an annual yield of about 1,000 Ph.D.'s.)

The special purpose research element provided 59 grants to 53 institutions for cross-disciplinary research and the stimulation of new research capabilities.

Significant progress was also made in expanding laboratory space at universities as nine facilities begun under previous grants were completed and occupied, and seven new facilities grants were allotted to institutions conducting research and training in support of the national space program. The newly completed structures provide over 280,000 sq. ft. of new laboratory area for space related research.

INTERNATIONAL AFFAIRS

Cooperative international flight projects and support activities were extended and new projects negotiated.

Satellite Projects

NASA launched the Canadian satellite ALOUETTE II from the Western Test Range on November 28. This launch was the second in a five-satellite series, the overall purpose of which is to provide information on the ionosphere throughout an eleven year period from solar minimum to solar maximum. In September, ALOUETTE I completed its third year of trouble-free operation in orbit. Over 120 scientific and technical papers and a number of scientific "firsts" have resulted from the operation of this spacecraft. The last three satellites in this series are scheduled to be launched by NASA in 1967, 1968, and 1969.

The first satellite launched in cooperation with France, FR-1, was placed in orbit on December 6 and is providing data on very low frequency radio wave propagation. NASA and the French National Center for Space Studies (CNES) have agreed in principle upon a second French satellite proposal. This experimental project will employ a satellite to locate and receive meteorological data from constant-level balloons.

On July 17, NASA and the German Federal Ministry for Scientific Research signed a Memorandum of Understanding providing for the launching of a German satellite to measure the spectra and flux of protons and electrons in the earth's inner radiation belt. Subject to preliminary tests of spacecraft instrumentation, it is planned to launch the satellite from the Western Test Range in 1968.

Progress continues on previously-agreed joint satellite projects with the European Space Research Organization (ESRO), Italy, and the United Kingdom. Two ESRO satellites are scheduled for launch on NASA vehicles in 1967; the second Italian (SAN MARCO) satellite in late 1966 or 1967, and the third NASA/U.K. satellite early in 1967.

During 1965, the total of foreign experiments contributed and selected for flight on NASA satellites rose to 16. These experiments include the tenth experiment proposal from the U.K. and the first proposal from Italy to be accepted by NASA. The second to reach flight stage was launched on the OGO-II spacecraft in October. Jointly instrumented by NASA and French scientists, it is observing airglow and aurora at visible and ultraviolet wave-lengths. Two additional experiments contributed by British scientists were launched on the Direct Measurement EXPLORER spacecraft in November.

Nine proposals for experiments to be included on the unmanned VOYAGER mission to Mars were received in response to a NASA "Announcement of Flight Opportunity" distributed widely within the international scientific community. These proposals, from scientists in Canada, France, Israel, Italy, the Netherlands, Sweden, Switzerland and the United Kingdom, were being evaluated along with proposals submitted by U.S. scientists.

Fifty-eight foreign ground stations in 28 countries plus Antarctica and Hong Kong have been receiving radio signals from the two BEACON EXPLORER satellites launched by NASA in October of last year and April of this year. A special session at next summer's COSPAR (Committee on Space Research) Symposium will be devoted to consideration of the results of these experiments.

Support of Manned Space Flights

Arrangements were made with a number of governments to permit the staging of contingency recovery aircraft at airfields in their countries, as required for GEMINI missions.

U.S. - Soviet Cooperation

The reciprocal exchange of conventional meteorological data between the U.S. and the U.S.S.R. continued over a special shared-cost communications link, pursuant to the Bilateral Space Agreement of June 8, 1962, and the implementing Memorandum of Understanding of November 5, 1964. These agreements provide for such exchange prior to and, on a secondary basis, during the exchange of satellite data. In New York in October, spokesmen for the Soviet side stated their expectation to have satellite meteorological data available on a continuing basis within "a few months."

On October 8, NASA and the Academy of Sciences of the U.S.S.R. signed an agreement for the preparation and publication of a joint review of research in space biology and medicine. This agreement provides for a joint Editorial Board and for full cooperation by both sides in the preparation of materials, the selection of authors, and the publication of their work.

Sounding Rockets

Cooperative sounding rocket launchings were conducted for the first time with the Netherlands and Brazil to obtain data on upper atmosphere winds and the effects of cosmic radiation on the ionosphere.

New sounding rocket projects were negotiated with Argentina, Brazil, India, New Zealand, Norway and Denmark, Pakistan, and the United Kingdom:

a. the agreements with Argentina and Brazil provide for the establishment of an inter-American experimental meteorological sounding rocket network (EXAMETNET), with launching stations in a north/south chain through the Western Hemisphere.

b. the agreement with the Indian Space Commission provides for the launching of twelve aeronomy, ionospheric physics, and magnetic field experiments from the international range at Thumba, India.

c. under the New Zealand agreement, NASA payloads were launched there to study the solar eclipse of May, 1965.

d. in Norway, ionospheric studies are to be conducted from the Andoya range, where the Norway/Denmark payloads will be launched.

e. Pakistan and the U. K. are cooperating with NASA in launching atmospheric research payloads from the Pakistani range at Sonmiani Beach.

Other cooperative international sounding rocket projects continued under existing agreements with France, India, Norway and Denmark, Pakistan, Sweden, and the United Kingdom. For example, synoptic meteorological rocket launchings in India and Pakistan continued from last year, and scientific papers prepared by meteorologists of both countries were presented at a COSPAR Symposium in the early summer.

In a multilateral sounding rocket project, scientists from France, Germany, Israel, Sweden, and the U. K. prepared special sampling surfaces to collect extraterrestrial dust for laboratory analysis. These surfaces were flown along with others prepared by U. S. scientists on a NASA AEROBEE sounding rocket from the White Sands Proving Ground in November.

The Canadian and the U. S. Governments signed an agreement for the continued operation of the Churchill Research Range, Fort Churchill, Manitoba. Under the terms of the agreement, the Canadian National Research Council (NRC) will take over operation of the range from the USAF and NASA will become the U. S. cooperating agency. The agreement, besides providing for the continued operation of this high-latitude sounding rocket launching facility, results in reduced costs for the U. S. Government.

As part of the International Quiet Sun Year (IQSY) program, a series of sounding rockets was launched from a converted aircraft carrier, the USNS CROATAN, in the Pacific Ocean off the coast of South America. The rockets were designed to probe the upper atmosphere and ionosphere strata in areas which cannot be reached by launchings from land. Scientists from Brazil, Chile, and Peru were observers on board the CROATAN.

Additional International Projects

Four experiments operated by Belgian, Dutch, Italian, and Swiss scientists were included in the NASA expedition observing the solar eclipse on May 30, 1965, from a jet aircraft flying in the vicinity of the Marquesas Islands in the South Pacific.

In February, diplomatic notes were exchanged with the Government of Mexico looking toward cooperation in a meteorological sounding rocket program, in the establishment of an automatic picture transmission (APT) station in Mexico, and in the testing of remote sensing devices from aircraft.

NASA continued to provide to the export control offices of the Departments of State and Commerce technical advice concerning the propriety of licensing the export of equipment and technology in the aerospace field.

Also during the year, letters were exchanged between NASA and the European Space Research Organization (ESRO) providing for the implementation of an earlier arrangement between the two agencies regarding exchange of scientific and technical information. NASA and ESRO will exchange bibliographies and documents in the open literature, microfiche copies of open reports, and material for bibliographic computer searches of the documents exchanged.

Tracking Network Stations

Agreement was reached with the United Kingdom for establishment of a NASA facility on Ascension Island to support Project APOLLO and the lunar and planetary program. An agreement with Australia was amended to provide for two new facilities--an 85-foot antenna for APOLLO support near Canberra and a station at Toowoomba to provide coverage for Advanced Technological Satellite. The existing agreements for tracking and data acquisition stations in Ecuador, and Mexico, were renewed.

Arrangements were in progress with Spain for expansion of the Madrid and Canary Island stations to accommodate APOLLO facilities. Arrangements were made for an additional facility at the Madrid station to support the increasing workload in the lunar and planetary program. Additional land needed for expansion of the NASA station near Tananarive was granted by the Malagasy Republic. Australia made available a site in Western Australia for use in astronaut visual acuity experiments during the flight of GEMINI V.

Planned ESRO/Alaska Station

The European Space Research Organization (ESRO) is taking preliminary steps to establish a telemetry/command station near Fairbanks, Alaska, to receive data from ESRO scientific satellites. Legislation was introduced into the Congress which would make ESRO eligible for benefits accorded other international agencies under the International Organizations Immunities Act.

Personnel Exchanges

Eighty-five scientists from 22 countries participated in the post-doctoral theoretical and experimental research program at NASA centers. In the second half of academic year 1964 and spring semester 1965 there were 52 NASA International University fellows enrolled in U. S. Universities. In the first half of academic year 1965 there were 26 fellows newly enrolled with 24 fellows continuing their studies. These students were co-sponsored and supported by their national or regional space committees.

Some 71 technicians from six countries and ESRO were trained at NASA centers in payload engineering, telemetry, tracking, radar, meteorology, launch procedures and range safety operations. Ten foreign students, sponsored by their national or regional space committees, attended a Summer Institute in Space Physics at Columbia University. And during the year about 5,000 foreign visitors--representing scientific and technical organizations, governments and overseas news media--toured NASA Headquarters and the Agency's field installations.

NASA-DOD COOPERATION

NASA transferred control of its two synchronous communications satellites (SYNCOM II and SYNCOM III) to the DOD, retaining only responsibility for coordinating all public demonstrations using the satellites and for handling requests by foreign countries to use the satellites.

NASA and the DOD consummated an agreement covering the acquisition and management of instrumentation aircraft for the APOLLO program. The Air Force Systems Command/National Range Division will manage the instrumentation of the aircraft. NASA will provide the specifications for the APOLLO equipment, and the National Range Division will provide the specifications for general-purpose range equipment. Scheduling of aircraft services will be accomplished by a joint NASA/DOD group.

NASA and the Army completed arrangements for the Corps of Engineers to perform certain real estate management services for NASA. Under these arrangements, the Corps of Engineers will lease to third parties NASA real estate not required for NASA missions.

NASA and the DOD completed arrangements for the joint conduct of a gravity gradient test satellite experiment. The Air Force Space Systems Division will manage the experiment, and NASA will provide funding and technical guidance.

NASA and the Army completed arrangements for the Army to assign certain technical administrative personnel to the Ames Research Center to participate in supersonic and VTOL aeronautical research of special interest to the Army.

NASA and the Defense Supply Agency agreed on procedures whereby the Defense Supply Agency will furnish logistical support to NASA for certain Federal supply classes.

NASA and the DOD agreed to certain principles concerning the management of NASA and DOD tracking and instrumentation facilities located at single or adjacent sites. This agreement established a policy of administrative management and logistic support of collocated facilities by a single agency.

NASA and the DOD established guidelines for the use and operation of the Churchill Research Range in Canada. The National Research Council of Canada will manage the range, and the U.S. operating costs of the range will be shared by NASA and the DOD.

NASA ORGANIZATIONAL AND MANAGERIAL CHANGES

A number of changes were made in NASA's organizational structure:

An organizational unit to be called the Office of the Administrator was established. It will include the Deputy Administrator and his assistants, the Associate Administrator and his assistants, and the Executive Secretariat.

The Executive Secretariat will be responsible for channeling, expediting, and scheduling the flow of work in the Office of the Administrator and for related supporting functions.

The Civilian-Military Liaison Committee, established by Section 204 of the National Aeronautics and Space Act of 1958, was abolished and its functions transferred to the President under terms of the President's Reorganization Plan No. 4 of 1965 as enacted into law.

All NASA launch operations activities were consolidated under the Director of the

John F. Kennedy Space Center (KSC). The consolidation was achieved by transferring responsibility for a Goddard Space Flight Center division already at KSC and for the Pacific Launch Operations Office, Lompoc, Calif., to the Director of KSC.

Phased project planning--a system of sequential phases in the approval and execution of major research and development projects--was formally established as NASA policy in October. In this system, each phase (Advanced Studies, Project Definition, Design, and Development/Operations) involves a combination of competitive industrial participation and complementary government in-house effort. The approach is designed to produce a maximum number of options for management decisions and to keep the options available as long as possible. The system increases flexibility for management to react favorably to technological breakthroughs and significant changes in Agency or national policy and requirements. Phased project planning is not an end in itself, but represents a major step in evolving a management pattern of maximum effectiveness.

NASA's Office of Advanced Research and Technology established a Mission Analysis Division at the Ames Research Center. The new Division is responsible for studying research and technology requirements of possible future NASA missions.

INDUSTRY AFFAIRS

During 1965, NASA continued to expand the use of incentive contracting, increasing the total value of outstanding incentive contracts from $500 million at the close of 1964 to over $2 billion at the end of this year. The Agency sought to further improve its incentive contracting procedures by awarding a contract to a management research firm to evaluate the effectiveness of major NASA incentive contracts.

Also, a NASA office was established within the Offices of the Deputy Director for Contract Administration Services, Defense Supply Agency (DSA), and NASA field offices were established at each of the 11 Defense Contract Administration Services Regions. This NASA/DSA organization provides a means for direct and efficient coordination (both at the field and headquarters levels) of matters related to the delegated administration of NASA contracts by the Defense Supply Agency.

In addition a NASA Office of Industry Affairs (Pentagon) was established within the Office of the Assistant Secretary of Defense (Installations and Logistics) for direct coordination and communication between NASA and the Department of Defense on such industry affairs matters as procurement, contract administration, quality assurance, and related subjects.

During 1965, NASA projects continued to experience a high frequency of work stoppages due to labor disputes between contractors and unions representing their employees. The NASA Office of Labor Relations, which carried out Agency responsibilities in this area, actively sought the cooperation of labor unions, contractors, and government agencies related to labor relations problems. The Agency received particularly great assistance from the members and staff of the President's Missile Sites Labor Commission, which has functioned since 1961 as the custodian of labor's pledge to the President to eliminate work stoppages on missile and space sites.

TECHNOLOGY UTILIZATION

During the year 1965, NASA stressed contractor reporting of new technology and arranged a pilot project with a major contractor to enlarge and emphasize its new technology reporting effort within the framework of existing contracts. Discussions were also held with other NASA contractors for similar new technology reporting programs.

Three hundred and fifteen Tech Briefs--one or two page bulletins to acquaint industry quickly with promising technological innovations generated by NASA's R&D effort--were published this year. This was a 50 percent increase over the previous year, bringing the total published to 535.

The program to develop more comprehensive special Technology Utilization publications, including booklength Technology Surveys (on topics such as inorganic coatings, valve technology, plasma jet technology) and selected bibliographies, increased 70 percent this year, and more than two dozen special Technology Utilization publications are now available to the public.

In the pilot dissemination effort, one new regional dissemination center was added at the University of New Mexico, bringing the total number of centers to eight. Last year, 29 companies were helping support the dissemination center program; this year the number has grown to over 100. More than 550 companies have received extensive service from the dissemination centers and more than 3,000 firms have been in contact with them for some degree of service.

DEPARTMENT OF DEFENSE

CHAPTER IV

INTRODUCTION

Department of Defense space and aeronautic activity during 1965 was paced by three significant events. (1) The TITAN IIIC, developing 2,400,000 pounds of thrust, successfully inaugurated its flight test program by placing 21,000 pounds of ballast payload into near-earth orbit; (2) The President directed the Department to proceed with the development of the Manned Orbiting Laboratory at development cost of about $1.5 billion; and (3) The Air Force was directed to proceed immediately to develop and produce a revolutionary new transport aircraft designated the C-5A at a cost of about $2 billion for development and the initial production of 58 units.

The Defense space program continues to mesh closely with the NASA effort and the efforts of the other government agencies whose activities are reported in this document. The DOD program continues to be a major contributor to the National Space Program. Technical, scientific and operational experience and informational interchange between DOD and other agencies of the government continue to insure that the space program of the United States is truly national in operation as well as in policy. The implementation of this stated national space policy is one of the recognized objectives of the military space program.

SPACE DEVELOPMENT ACTIVITIES

Manned Orbiting Laboratory (MOL)

On 25 August 1965, approval was granted the Department of Defense to proceed with the development of a Manned Orbiting Laboratory. This program was initiated in December 1963 to determine the military usefulness of man in space. During the succeeding year, intensive study by the Air Force and Navy, with industrial support, resulted in broader program goals and a wider definition of the areas of principal interest.

The objectives of the approved MOL program are to:

a. learn more about what man is able to do in space and how that ability can be used for military purposes.

b. develop technology and equipment which will help advance manned and unmanned space flight, and

c. experiment with this technology and equipment.

The laboratory will be equipped to accommodate two men in orbit for about 30 days and to provide them with pressurized and unpressurized experimental working space adequate for the planned activities. The orbital vehicle will be ten feet in diameter and about 50 feet long.

A modified GEMINI capsule, GEMINI B, will be used to house the men during transport to orbit and to return them to earth following the orbital mission. Access to the laboratory in orbit, from the capsule, will be through a hatch in the heat shield and a pressurized tunnel.

The planned launch vehicle is the TITAN IIIC. The manned launches will be flown out of the Western Test Range and will be accomplished with the assistance of seven segment solid rocket motors rather than the five segment motors employed in the early vehicle development flights. These larger motors will provide about 20% increase in low orbit payload capability.

The ground network for tracking and orbital control will be based on the best choices of existing DOD and NASA facilities. This network will be determined, with NASA participation, during the current Contract Definition period.

There will be at least five manned launches in the presently conceived program extending into CY 1970. There will be early unmanned launches using TITAN IIIC vehicles from the current vehicle development program. These launches are due to begin late next year or early 1967 out of the Eastern Test Range. The initial unmanned launch of a fully-equipped MOL will test critical elements of the system including the modified GEMINI and the laboratory module.

NASA will examine the MOL to determine the feasibility of executing experiments of a general scientific and technological interest. The Air Force will accommodate these experiments on a minimum interference basis.

As in the past, NASA and DOD will continue to work closely together to insure that the manned space flight effort of both agencies is fully coordinated. Although the MOL will primarily have defense objectives, the continued close relationship between DOD and NASA will insure that the program remains integrated with the national effort.

Astronaut candidates are military test pilots and graduates of the Aerospace Research Pilot School at Edwards Air Force Base, California.

The MOL program advanced into the Contract Definition Phase in the latter half of 1965. The purpose of this phase is to complete the engineering definition, to establish the base line configuration and to initiate developmental hardware procurement.

TITAN III Program

The flight test program of TITAN III initiated in 1964, continued with a high degree of success during 1965. Five flights were flown--two TITAN IIIA's and three TITAN IIIC's.

The third TITAN IIIA of the program was launched February 1965, and injected a communication research satellite into orbit. On May 6, 1965, the next and fourth TITAN IIIA was launched from Cape Kennedy. Two payloads were carried aboard this flight and successfully injected into planned orbits. Payloads were an experimental communication satellite (LES-2) and a radar calibration sphere.

The highly successful TITAN IIIA flights resulted in a decision to cancel the one remaining planned TITAN IIIA flight and convert the vehicle to a TITAN IIIC configuration. Flight test planning and activity then centered on the launch of the first TITAN IIIC configured vehicle. The initial flight of the first TITAN IIIC occurred on June 18, 1965. Three notable space records were achieved in the course of its first flight:

a. most powerful vehicle ever launched with the booster solid rocket motors developing 2,400,000 pounds of thrust at lift-off.

b. most powerful rocket engine ever ignited in flight. These engines developed 470,000 pounds of thrust when started at altitude.

c. one of the heaviest payloads ever orbited by a vehicle (TITAN IIIC's Transtage, which propelled the 21,000 pound ballast payload into orbit, is not included as part of payload weight).

The second and third TITAN IIIC's were launched in October and December and both further contributed to the progress of the R&D program. After achieving orbit, some difficulties were encountered in the Transtage on both the October and December TITAN IIIC flights which resulted in only partial mission successes. However, in the latter case the scheduled payloads were placed in orbit.

At Cape Kennedy the Integrated Transfer Launch (ITL) facilities were completed for the TITAN III. This is a dual launch pad facility and provides a high launch rate capability.

Recognizing the need to be responsive to all payloads and mission requirements, effort has been initiated to achieve an initial launch capability at the Western Test Range. This capability will provide support for polar or near polar mission requirements that would be degraded if flown from Cape Kennedy.

Early in the year, an examination of requirements for the TITAN III led to an adjustment of the R&D program schedule. This step was taken to insure better compatibility between the completion date of the R&D program and the time period when operational use of the TITAN III is anticipated. Thus, the remaining TITAN IIIC vehicles will be flown at regular intervals over the next eighteen months, and will be assigned useful engineering payloads.

DOD Satellite Communications Activities

The present satellite communications activities within DOD reflect, in the broadest sense, four important factors:

a. the continued vital United States need for prompt, reliable, secure and flexible communications to support its global responsibilities, command its global forces, and control its weapons.

b. the demonstrated ability of orbiting satellite repeaters, when used with appropriate surface terminals and transmission techniques and incorporated into proper overall system designs, to provide communications channels which are much more survivable, reliable, flexible and secure than those generally available through the use of high frequency radio, undersea cable, and similar conventional schemes.

c. the growing reliability of powerful boosters and sophisticated satellites which promise to provide novel and economic means of meeting very difficult tactical-mobile communications needs; and

d. the emergence of the Communications Satellite Corporation as an important element in national commercial and military communications planning.

<u>Defense Communications Satellite Program (DCSP)</u>

The objective of the Defense Communications Satellite Program is "to develop the technology required for an operational system in a timely manner." With the Defense Communications Agency acting as the focal point, the Army has the responsibility for the surface environment comprised of fixed and transportable ground stations, the Navy has the responsibility for shipborne stations and the Air Force is responsible for the satellites, and launch vehicles. The Defense Communications Agency is responsible for the operation of the Satellite Communications Control Facility.

To accomplish the DCSP objective, the program has been divided into three projects as follows:

a. SYNCOM

b. Initial Defense Communications Satellite Project (IDCSP)

c. Advance Defense Communications Satellite Project (ADCSP)

SYNCOM was a joint effort between the National Aeronautics and Space Administration and the Department of Defense to demonstrate the feasibility of communication via synchronous satellite.

In March 1965 NASA completed the maneuvering of SYNCOM II over the Indian Ocean to stop its westward movement and to allow the satellite to stabilize its position at the triaxial nodal point near 77°E longitude. The estimated remaining communications life of SYNCOM II is two years.

Complete control of the SYNCOM Satellites (II and III) was transferred from NASA to DOD on 1 April 1965. Control of the satellites, i.e., tracking, ephemeris computations, commanding and telemetry readout and analysis was assumed on that date by the USAF. Satellite usage and scheduling control was retained by DCA. The U.S. Army continues to operate and maintain the associated ground communication stations and to conduct the various R&D tests.

During the past year DOD has conducted a number of technical and operational R&D tests. The basic engineering tests conducted by DOD for NASA were completed in March 1965. Tests to determine the effect of satellite communications on various types of data transmission have continued since DOD assumed control of the satellites. Ground communications stations are at various locations throughout the world. A terminal located at Camp Roberts, California, was in use until September 1965 when its modification for use with the IDCSP began. Another terminal, installed on the USNS Kingsport has participated in numerous tests, its use to support the GEMINI flights being the most important during 1965.

SYNCOM III was kept on station between 170° and 174°E longitude until October 1965. Since then the satellite was given a westward drift. It is currently planned to keep the satellite between 135° and 162°E longitude if sufficient control gas remains to stop the satellite when it reaches 135°E longitude in approximately three years. The SYNCOM III communications life remaining is estimated to be no less than five years.

Initial Defense Communications Satellite Project (IDCSP)

The basic objectives of the Initial Defense Communications Satellite Program are as follows:

a. perform research, development, test, and evaluation to demonstrate system operational feasibility.

b. obtain an emergency capability as early as possible to supplement the Defense Communications System for essential command and control.

c. establish a research and development system in being, convertible and expandable to an operational system.

The IDCSP is divided into two phases. During the first phase, research and development assets will be deployed to provide a number of earth terminals and randomly dispersed satellites for system test and evaluation. The initial ground system will consist of two terminals in CONUS, two in West Europe, two in Africa, two in the Western Pacific, and two in Hawaii. The space system will be established by three TITAN IIIC R&D launches, carrying eight communications satellites each, to be injected into a near-synchronous equatorial orbit. Each satellite will be given a different drift rate to achieve random dispersion.

Following the test and evaluation phase, the IDCSP will provide a limited communications capability to satisfy certain unique and vital requirements of the DOD. Additional terminals will be acquired and deployed to establish communications links in accordance with military requirements validated by the Joint Chiefs of Staff. Most of these additional terminals will be lightweight and highly transportable. The satellite population will gradually degrade due to normal satellite failures; a replenishment launch is planned approximately two years after the initial launch.

Advanced Defense Communications Satellite Project (ADCSP)

The Defense Communications Agency conducted operational and technical requirements definition and system definition studies which would define an Advanced Defense Communications Satellite Project (ADCSP). The objective of this ADCSP is to provide the Department of Defense with an operational communications satellite capability late in this decade and beyond to more fully satisfy unique and vital national security needs. Six funded contractual approaches and specific inputs from each of the services are being obtained. The composite system design will incorporate the best elements of each.

Tactical Satellite Communications Program (TSCP)

Tactical/Mobile satellite communications studies were inaugurated in 1965 with an initial analytical study being conducted by R&D and operational personnel of the three Services.

The first DOD effort in the tactical-mobile field will involve an experiment primarily addressed toward improving the long range communications of the Air Force's Strategic Air Command. A satellite repeater will be placed into a high orbit as a piggyback payload from a TITAN IIIC development launch late next year. Several SAC aircraft as well as Army and Navy mobile terminals will be employed, under operating conditions, to study methods of utilizing such a satellite repeater and observing the specific value of having available secure teletype channels of extremely high reliability and great range.

Experimental Communications Satellites

Two experimental satellites were placed in orbit on 6 May 1965 as a "bonus" payload on the fourth TITAN IIIA launch. One satellite, designated LES-2, is a communications transponder and the second of a series of experimental satellites designed to test realistically, in a 1500 and 8000 nautical mile elliptical orbit, a number of devices and techniques being developed for possible use in future military communication satellites and satellite communication systems. The second payload was a 44-1/2 inch diameter aluminum sphere weighing about 75 pounds placed in a 1500 nautical mile orbit for use as a test target to calibrate powerful radar and radio systems.

The LES-2 satellite is being used to test such devices and techniques as an all solid state communications transponder, an earth sensing and antenna switching system to attain antenna gain from a spinning spacecraft, a magnetic spinning spacecraft, and a magnetic spin axis control system to increase power output.

Project WEST FORD

In 1965, orbital decay measurements of 480 million fibers 1.8 centimeters long and .0018 centimeters in diameter placed into orbit for Project WEST FORD, confirmed predictions that the first particles will reenter the earth's atmosphere in February 1968 and be consumed in the process.

Technological advances in active space communication satellites have resulted in decreased interest in passive reflectors. As a result, no further launches of reflective dipoles are contemplated at this time.

Spaceborne Nuclear Detection (VELA)

The VELA Satellite Program is designed to develop a satellite-based nuclear detection capability for events occurring on the earth's surface to the outer reaches of deep space. It is a research and development program of the Advanced Research Projects Agency, and is conducted jointly by the USAF and AEC.

Two more VELA satellites were launched into orbit in July 1965. The first four, which were orbited in 1963 and 1964 are still operating. These satellites are providing useful information on radiation background and the operation of nuclear test detection sensors in space. They also provide an interim monitoring capability for detecting clandestine nuclear explosions at high altitude and in space, which is particularly significant because of the Nuclear Test Ban Treaty. All of these satellites have been launched from Cape Kennedy into near-circular orbits about 60,000 nautical miles from the earth. With each launching, they have contained improved and additional sensors to investigate nuclear test detection capabilities and to establish a better baseline of space background radiations. The radiation background data is also of general interest to the scientific community for studies of particles trapped in the earth's magnetosphere and solar and galactic radiation. The test data is being used by the DOD in cost and capability studies of various concepts of worldwide operational nuclear detection systems.

Space Surveillance

The Advanced Research Projects Agency, the Air Force, and the Navy are conducting research in space object identification to determine the extent and best means by which the physical characteristics of uncooperating objects in earth orbit can be determined through observations by ground-based radar. In addition to providing a possible source of diagnostic information on our own satellites in orbit, such advanced radar techniques should make available continuing technology for updating the capabilities of the Space Surveillance and Detection Tracking System (SPADATS) in support of anti-satellite systems.

Geodetic Satellite

The Department of Defense continued its active participation in the National Satellite Geodetic Program during 1965. The NASA's EXPLORER XXIX satellite, (GEOS I) launched November 6, 1965, is being observed and tracked on a worldwide basis by DOD as well as other participating Government agencies. EXPLORER XXIX carries an Army SECOR transponder, a NASA Range-Range Rate transponder and LASER reflector, an Air Force optical beacon, and a Navy Doppler beacon. The project will continue to provide more precise information about the earth's size, shape, mass and variations in gravity and precise determinations of locations for accurate mapping and charting.

Two additional geodetic SECOR (Sequential Collation of Range) satellites were successfully orbited in 1965. These spacecraft are being used, as part of the Department of Defense effort, in the Army Corps of Engineers geodetic satellite program to locate the positions of certain Pacific Islands and the North American datum. Tests of techniques for using SECOR satellites at higher altitudes have been initiated as the first step in a project to locate points in an around-the-world belt. The objective of this program is to improve our knowledge of the earth's diameter and to connect all major geodetic datums. The SECOR system is producing accuracies of one part in two hundred thousand.

The Navy is routinely determining the positions of tracking stations anywhere on earth to an accuracy of about 25 meters with respect to the earth's center of mass. The same Doppler data is used to determine the harmonic coefficients of the earth's gravity field. Coefficients through the eighth order have been published. This accuracy is sufficient to allow the prediction of a satellite's position changes due to gravity field variations to an accuracy of better than 75 meters over a 24-hour period. This figure compares with a probable error of well over a mile, five years ago. The Doppler beacons in the Navy Navigation Satellites, as well as those in the NASA Beacon Explorer Satellites, are being used for this purpose.

Navigation Satellite Program

The Navy Navigation Satellite System, which was declared operational by the Department of Defense in July 1964, has continued to operate satisfactorily during the past year. The system at the present time is providing accurate navigation information to submarines and selected surface ships. During 1965, the satellite navigation capability has been expanded by installing receiver equipment aboard attack aircraft carriers operating in Southeast Asia. This addition of worldwide all-weather accurate navigation capability has proven to be extremely valuable to the attack carrier mission. In an effort to simplify navigation satellites and the navigation receiver equipment, the Navy, during 1965, began an investigation into the feasibility of long term orbital predictions that would make possible the publishing of an ephemeris almanac for use aboard ship. The Navy is also seeking to increase the cost effectiveness of this system by developing a family of receiver equipment that could be used in differential positioning in aircraft and in smaller ships. The Navy is continuing to stress the development of satellite reliability and mean-time between failure in order to achieve a five-year satellite lifetime in orbit.

SPACE GROUND SUPPORT

DOD National Ranges

The 1964 realignment of the National Range Complex to provide centralized planning and management of this $3 billion capital plant resulted in cost savings and a better response to NASA and DOD programs. A decision to provide a national fleet of instrumented range aircraft to meet both DOD and NASA needs deleted the requirement for six additional jet aircraft, thereby avoiding a heavy capital investment and an annual operation cost of approximately $3.9 million. DOD and NASA reached agreement on the division of responsibilities in management and operation of collocated ground-tracking stations. The agreement covers policies and responsibilities for mutual support, operation and management, and is expected to result in significant economies at these stations. On 1 May 1965, the Canton Island Station was transferred to NASA and on 1 June 1965 the Kokee Park, Hawaii Station was transferred to NASA. The South Point, Hawaii Tracking Station was deactivated on 30 September 1965 and its workload transferred to the NASA Kokee Park and Air Force Kaena Point Stations.

Under the concept of a combined range instrumented ship fleet to support all programs anywhere in the world, the USS H.H. Arnold and the USS H.S. Vandenberg were re-deployed from the Atlantic to the Pacific to support penetration aid and modified and instrumented reentry systems testing. The first of five range ships being built in support of the APOLLO program by joint Navy-Air Force-NASA efforts was launched on 9 September 1965.

On 1 February 1965, the Air Force Western Test Range assumed responsibility from the Navy's Pacific Missile Range for range functions in support of missile and space system launches from Vandenberg Air Force Base. This action was in compliance with a DOD decision to establish a Pacific area ICBM and space vehicle range.

Space Detection and Tracking System (SPADATS)

The Air Force SPACETRACK System together with the Navy Space Surveillance System (SPASUR) make up the principal elements of the North American Air Defense Command SPADATS. This global system detects, tracks and catalogues all space objects in earth orbit. SPADATS functions not only as a defensive detection and tracking system, but performs important functions in assisting our national manned space flight program. During the NASA GEMINI 5 rendezvous and docking radar pod experiment, SPADATS provided the astronauts with frequently updated traffic forecasts, i.e., positions of other space objects relative to the GEMINI 5 spacecraft. During those periods of flight when the spacecraft beacon was ineffective because of spacecraft electrical power problems, SPADATS provided NASA with the primary tracking data. Additionally, SPADATS provided the only source of information concerning separation distance between GEMINI 5 and the radar evaluation pod which was co-orbiting with the GEMINI vehicle.

AERONAUTICS DEVELOPMENT ACTIVITY

C-5A Transport Aircraft

The Air Force, in October 1965, was directed to proceed immediately to develop and to produce a revolutionary new transport aircraft, the C-5A. The gross weight of this airplane will be more than 700,000 pounds or 350 tons at take-off. This is more than twice the weight of the largest military cargo plane today. This new aircraft will be able to carry loads of 220,000 pounds over distances of 3200 miles. For nonstop hauls across such large distances as the Pacific, the plane will have a capability of carrying 100,000 pounds as payload. It will be more than 230 feet long, 63 feet high and have a wing span of about 220 feet. The development cost and the initial production order for 58 airplanes, including the engines, will be about $2 billion.

The aircraft and its engines will be bought under a new purchasing concept within which both the airframe and the engine manufacturers will receive contracts to cover not only the research and development of the aircraft but also its production.

This should assure that this large and complex program will be carried out at the lowest possible cost. The C-5A will be able to land on support area air fields approximately 4,000 feet in length, which is a short landing distance for an aircraft of this size.

The C-5A will greatly extend the capability of support over large distances. The plane will carry almost any piece of military equipment, including tanks, trucks, and helicopters. For example, sixteen three-quarter ton trucks can be carried by the aircraft or two M-60 Main Battle Tanks. Ten C-5A's could have handled the entire Berlin Airlift, an operation which at its peak utilized 308 different aircraft. This new aircraft will greatly improve our military transport capabilities.

C-141A Transport Aircraft

The new C-141A cargo transport aircraft received its FAA certification on schedule in January 1965. The first C-141A operational squadron for the Military Air Transport Service was fully equipped on schedule in July 1965, and a rapid buildup in production delivery rate was accomplished during the year. The C-141A is providing a significant improvement in speed and delivery capability for the nation's airlift.

F-111

During 1965, seven F-111A and three F-111B RDT&E aircraft were delivered on schedule. The F-111A demonstrated its wing sweep features and achieved a maximum sustained speed of Mach 2.2. The flight test program of the Air Force and Navy aircraft proceeded basically on schedule and accumulated more than 400 hours of flight experience. The aircraft performance indicated high reliability and excellent maintenance characteristics as a result of flight test activity.

A multi-year production contract was issued in April 1965 for 431 F-111A (AF) and F-111B (Navy) aircraft. A total program is currently planned which includes F-111A, F-111B, RF-111A and FB-111 aircraft. The FB-111 will be a bomber version of the F-111A. Minimum configuration changes will be incorporated in the FB111 to permit greater navigation accuracy and higher gross takeoff weights.

A reconnaissance configuration of the F-111A was also approved for development in 1965. The RF-111A configuration, like the FB-111 will require only minimum modifications and retain maximum commonality with the basic F-111A.

Australia is the first foreign government to order F-111A aircraft. The British have also indicated interest in the F-111A and negotiations are continuing. The British tentatively selected a desired configuration for the UK F-111 and will make a final decision in early 1966 on the option to buy.

A-7 Light Attack Aircraft

The Navy program to develop an improved light attack aircraft (a major modification of the F-8 fighter aircraft) progressed very satisfactorily. The first flight was made in September 1965, nearly a month ahead of schedule. The A-7A is a turbo-fan powered visual attack aircraft with significantly improved payload-range capability and cost-effectiveness over the current light attack aircraft it will replace.

XB-70 Flight Test Program

The second of the two XB-70 aircraft made its first flight on 17 July 1965. The two aircraft since then have been involved in a flight test program aimed at establishing their airworthiness, opening up the flight envelope to Mach 3 (2000 mph), and finally demonstrating 30 minutes sustained flight at Mach 3 in the 500°+F temperature environment. The first Mach 3 flight was on 14 October 1965.

While attaining these objectives the XB-70's are making important contributions in design verification, flight dynamics, structures, heat transfer, engine-air inlet optimization, and sonic boom measurements.

Negotiations are underway to develop a follow-on joint USAF/NASA Flight Research Program beyond the current program which is scheduled to be completed in April 1966.

Coin Aircraft

An accelerated flight test program of the OV-10A Light Armed Reconnaissance Aircraft (LARA) progressed well during 1965. Assuming the outcome of these tests to be favorable, a version of this aircraft, the OV-10, will begin to enter the USAF and Navy-Marine operational inventories by early 1967.

The aircraft first flew on July 16, 1965, and is proceeding satisfactorily through the Navy-Contractor Test Program. An All-Service Evaluation Group based at the Naval Air Test Center, Patuxent River, Maryland, will thoroughly develop all operational concepts and tactics commencing in May 1966.

LARA is basically a twin engine turboprop aircraft, with short takeoff and landing performance from unimproved fields, roads and aircraft carriers without the use of arresting gear. In addition to weapon delivery missions, the aircraft is designed for light logistic duty carrying five paratroopers or 3000 pounds of cargo.

This aircraft (or variants thereof) if accepted for production, will provide replacements for USAF O-1's, T-28's, A-1E's, B-26's, C-46's and C-47's. The Marines will use the OV-10 as a replacement for the 0-1 and the armed HU-1 in the helicopter escort and reconnaissance role. Introduction of this aircraft into the Military Assistance Program at an early date is also a possibility.

Helicopter Development

DOD is continuing a development program oriented toward improving helicopter performance and handling qualities which will be fully responsive to the requirements of a ground commander in a combat environment.

During 1965, the Army awarded the initial production multi-year contract for 714 of the Army's newly developed Light Observation Helicopters (LOH) designated the OH-6A (PAWNEE). This aircraft represents significant advances in the state-of-the-art for light helicopters. For example, it has less than half the equivalent flat plate drag area, half the maintenance man hours per flight hour ratio, and approximately twice the useful load to empty weight ratio of the aircraft that it will replace.

A high speed helicopter research program was completed by the Army during 1965. Several helicopters with different rotor and control systems were modified to a compound configuration by the installation of wings to unload the rotors at high speeds and auxiliary power systems for additional horizontal thrust. Three of the compound helicopters demonstrated a high speed capability by flying in the 200-knot class.

A program for engineering development of prototypes for the Advanced Aerial Fire Support System (AAFSS) for the Army has been approved. This system will utilize a winged compound helicopter designed for use in providing organic aerial gunfire support for Army Units.

During the first half of 1965 the conceptual and the military potential evaluation of the CH-54A continued. The crane version of the CH-54A completed the FAA certification program and an FAA type certificate, Restricted Category, was issued 30 July 1965. The aircraft was type classified Limited Production in August 1965 and four of the CH-54A's were deployed to Viet Nam with the 1st Cavalry Division, Air Mobile, in September 1965.

The XV-9A advanced research helicopter completed a flight test program. The XV-9A incorporates the hot cycle propulsion system which employs the principle of piping hot gases through the rotor hub and rotor blades and exhausting the gases out at the blade tips. This system eliminates the need for heavy and expensive gear drives. This program has demonstrated that the hot cycle propulsion system can be competitive with other propulsion systems for heavy lift helicopters.

Vertical and Short Take-Off and Landing Program (V/STOL)

The XV-5A (fan-in-wing) has completed both the contractor and the military flight evaluation. One of the two aircraft is being modified to enable the program to continue and to provide the Army with some limited operational data. The aircraft will also be used to train the pilots from the other Services and NASA to fly a fan-in-wing V/STOL aircraft.

The XV-6A (P-1127), a diverted thrust aircraft built in the United Kingdom, was used in a tripartite, tri-Service V/STOL operational concept evaluation in England between April and November 1965. A total of nine operational evaluation aircraft were built employing a 15,200 pound diverted thrust engine. An international squadron composed of pilots and technical personnel from the three participating countries (US, UK, FRG) conducted this evaluation. A total of approximately 1,000 sorties were flown as part of the overall program to determine the feasibility of employing V/STOL aircraft in operations from both prepared and unprepared sites. During the early part of 1966, all hardware developed during this program will be divided equally among the three countries, in order that each may conduct national trials according to their own desires. This tri-Service program was managed by the U.S. Army. It is anticipated that each of the three Services will conduct operational trials during the Spring and Summer of 1966.

The Army, Navy and Air Force entered the operational evaluation phase of the tri-Service V/STOL program in 1965.

The development and flight test of V/STOL transport type aircraft following three different V/STOL concepts was continued by the three military services. The tilt wing XC-142A V/STOL transport program produced more than 150 hours of flight test time on four of the five aircraft in this program. After successful hover demonstration program completion, the aircraft was transitioned through all modes of flight on January 11, 1965. On that date the XC-142A made its first complete flight consisting of a vertical takeoff, transition to full conventional flight and converting back to hover flight for a vertical landing. This maneuver has become routime for the XC-142A since that time.

The X-19A, a tandem tilt-propeller design, suffered a setback on 25 August 1965 when the No. 1 aircraft in the two-aircraft program was destroyed during a test flight at Atlantic City, New Jersey. The No. 2 X-19A has not yet reached the flight test phase.

The first of two X-22A aircraft, a rotating ducted-propeller design, was delivered in May 1965 and flight testing will begin early in 1966 after extensive ground testing.

X-15 Research Aircraft

The primary role of the X-15 in 1965 was support of advanced aerospace sciences experiments. The joint Air Force/NASA X-15 test team used the aircraft as a test bed for a series of experimental payloads supporting environmental studies, development of improved components for future aerospace vehicles, and basic aerothermodynamic research. The X-15 is ideally suited to this mission because it can achieve test conditions in the hypersonic speed range and space equivalent altitudes, with excellent reliability and bring the test equipment back for laboratory examination and reuse. There have been twenty-seven approved experiments sponsored by the Air Force, NASA, DOD and FAA. Of the twenty-seven, three have been completed, two cancelled, two combined with other tests, and six await delivery of test hardware. Fourteen experiments were in active flight test during 1965.

SUPPORTING RESEARCH AND TECHNOLOGY

Over-the-Horizon Radar

The Department of Defense has developed a family of Over-the-Horizon radars capable of detecting aircraft and missiles far beyond the radar or line of sight horizon. These new systems will bounce radar signals off the ionosphere and send them to the surface of the earth several thousand miles beyond the horizon. Previously, radar capability had been limited to detection of objects within line of sight. Fabrication of the first Over-the-Horizon operational radar was completed in 1965 and the installation was nearing completion at the close of the year. This radar is designed to detect missiles during the launch phase and will provide a capability for earlier warning than before of hostile missile launches.

Laboratory and field evaluation of advanced techniques continues at a rapid pace and results are being assessed in terms of Air Force, Army, and Navy requirements.

Spacecraft Technology and Advanced Re-entry (START)

The DOD lifting re-entry technology efforts are contained within a single advanced development program element entitled Spacecraft Technology and Advanced Re-entry Tests (START). The programs are spread across the spectrum of the lifting body re-entry flight regime.

The ASSET program was based on flight tests of a simple radiatively cooled glide vehicle without aerodynamic controls and was essentially finished in 1965. The last of six flights from the Eastern Test Range was successfully completed on 23 February 1965. Data were obtained in large volume from five of the six flights and reduction of these data consumed the remainder of 1965.

The second portion of the START program consists of ablatively cooled SV-5 vehicles equipped with aerodynamic controls. This particular re-entry vehicle is being designed for the purpose of returning data capsules from orbit. The program in 1965 was in the initial stages of hypersonic re-entry vehicle fabrication, component selection, and proof testing of those components.

Space Power Equipment

The DOD continued to examine various concepts for meeting anticipated electrical power requirements of future satellites. The 500-watt SNAP 10A nuclear reactor power unit, a major development effort in the AEC funded SNAPSHOT program, was successfully placed in orbit on April 3, 1965. The SNAP 10A produced power for 43 days following the launch.

Another Space Power development of interest to DOD is the Advanced Solar Turbo Electric Concept which uses the sun as the energy source. Solar radiation heats a working fluid which transmits energy to a turbine. The turbine, in turn, drives an alternator resulting in the production of electrical power from solar energy. During 1965, candidate sample materials for a petal type solar collector were evaluated in ground laboratories to determine degradation under simulated space environmental conditions.

Rocket Propulsion Technology

The DOD maintains a broad gauged research and technology program in chemical rocket propulsion, including propellant systems, solid motors, liquid engines, hybrid systems, air augmented rockets, nozzles, cases, and controls. Much of this technology is directly applicable to space boosters and spacecraft propulsion. The following items illustrate the nature of the space-related activity in 1965.

The Air Force has undertaken a program to demonstrate an advanced storable liquid propellant engine which consolidates many exploratory development advances in turbopumps, combustion chambers, and nozzles. This engine will improve performance with proven propellants to such a degree that single stage vehicles for ICBM and possibly low orbit missions become practical. This program is based on the modular engine concept which greatly reduces the time and cost traditionally associated with the development of large liquid engines, while enhancing the reliability and versatility of the product.

The Air Force and NASA are cooperating in an advanced technology program which has for its objective the demonstration of a high performance, high pressure hydrogen-oxygen engine affording very substantial improvements in thrust-to-weight ratio and delivered specific impulse. This engine will also be capable of multiple-restart, long-duration, variable-thrust operation. Developed on the modular concept, the new engine can serve both in a high energy upper-stage, and, in a variety of clustered configurations in a versatile space booster. This technology is considered to be prerequisite to the development of a reusable space launch vehicle.

Significant effort is being placed under exploratory and advanced development programs on supersonic combustion ramjet systems. The feasibility of supersonic combustion under laboratory conditions simulating hypersonic flight has been demonstrated, but the design of efficient aerodynamic structures and inlets for high dynamic pressure trajectories represents a development challenge. In the development of the supersonic ramjet or scramjet engine, DOD and NASA are again pursuing complementary programs. NASA, for example, is planning to employ the X-15 rocket plane as a hypersonic test bed for scramjet experimentation and evaluation. The Air Force and the Navy are both pursuing extensive experimental programs as well as sponsoring analytical studies on the application of scramjet propulsion to hypersonic vehicles and possible integration with rocket powerplants.

In the field of solid propellants, the principal space interest centers on the 156-inch solid propellant motor. Thus far, five complete segmented motors have been successfully fired at thrust levels ranging from one million to three million pounds. Two were equipped with jet tabs for thrust vector control and one with a single large movable nozzle. The test loading and firing of a 156-inch fiberglass case motor is scheduled for July 1966. Other objectives of this technology program include the following: Motor quench, nozzle materials, submerged nozzle, hot gas valve thrust vector control, and integrated nozzle closure. The use of large solid motors as space boosters has been impressively demonstrated in the TITAN IIIC program.

Flexible-Wing Systems

The Advanced Research Projects Agency's flexible-wing program continues toward the development of low-cost, high performance aerial delivery devices for use in remote areas. Improved prototypes of the unique precision drop glider are being developed for military acceptability tests, while studies and tests on a manned-powered glider and a towed glider continue to provide information necessary to assess their utility and value in performing a variety of counterinsurgency and civil action missions for indigenous forces in remote areas. Tests and studies to date indicate the drop glider can perform precise, all-weather delivery of personnel and cargo from aircraft at safe stand-off distances, while the manned, powered glider shows good potential as a simple, inexpensive and rugged utility aircraft for use by indigenous forces.

Gravity Gradient Stabilization for Satellites

During 1965, the Navy conducted two significant gravity gradient experiments. On March 9, 1965, two satellites were launched as secondary payloads aboard an Air Force THOR AGENA booster. These were the first two-axis and three-axis gravity gradient stabilization experiments to be performed.

Two other gravity gradient stabilization experiments were being designed during 1965 in support of the Defense Communications Satellite Program. The Air Force is sponsoring a two-axis stabilization experiment at near synchronous altitude. The Navy, also in support of the DCSP, is fabricating a spacecraft experiment to demonstrate three-axis stabilization at near synchronous orbital altitude. The results of these experiments are intended to assess the applicability of utilizing this stabilization technique at near synchronous altitudes for improving the communication system capability.

Despun Satellite Antenna (DATS)

Application studies of phased array antennas to communication satellites was requested of the USAF by DCA in September 1963. At the completion of the initial study contract the results will permit a planned space test of an electronically despun antenna. This will be done as a part of a research and technology TITAN IIIC satellite launch in late 1966 or early 1967. This antenna will enable the satellite to perform more efficiently and achieve full earth coverage. Thus the DATS is an alternative means to the gravity gradient oriented antenna for increasing satellite antenna gain.

General Support, Research and Development

During 1965, under Project HARP, the U.S. Department of the Army and the Canadian Department of Defence Production continued research and development of high altitude research probes utilizing a 16-inch, smooth bore gun emplaced on Barbados, British West Indies. Passive and active atmospheric sensors were fired to a maximum elevation of 455,000 feet. Wind direction and speed were obtained by radar tracking of chaff and aluminized parachutes. Wind shears were acquired by camera theodolites tracking the luminescent trails created by release of tri-methylaluminum in the upper atmosphere. Solid-state, electronic telemetry components were developed to transmit atmospheric temperatures to receivers on the ground; these were fired successfully from 5-inch, 7-inch, and 16-inch guns, where acceleration forces from 8,000 to 50,000 g's existed.

The Naval Research Laboratory (NRL) supported a research satellite named "AURORA." The objectives were to make spectrophotometric measurements on both day and night aurora, simultaneously measure particle fluxes in and about the magnetosphere, and then to correlate the particle and spectral data with each other, with solar phenomena, and with terrestrial phenomena such as magnetic storms.

NRL also supported Professor J. A. Van Allen at the State University of Iowa in his research to extend knowledge of (1) radiation in outer space: galactic and solar cosmic rays; solar wind; particles trapped in the earth's magnetic field; and (2) solar terrestrial phenomena associated with these radiations. The research effort was extended to include studies of solar and galactic X-rays; VLF radio propagation in the magnetosphere; RF emissions of various objects in the solar system; and investigations of the interaction of the moon with the solar system; and investigation of the interaction of the moon with the solar wind. Data from INJUN I, INJUN II, EXPLORER XII, EXPLORER XIV, RELAY I, RELAY II, and MARINER II were studied.

A Solar Radiation Monitoring Satellite, designed and fabricated by the Naval Research Laboratory (NRL) was successfully launched as a secondary payload aboard an Air Force THOR AGENA from the Western Test Range during the week of 7 March 1965. The solar monitoring satellite was injected into a nominal 500 nautical mile circular orbit inclined 70 degrees to the earth's equator. Tracking and data acquisition services are being provided by ten NASA and two NRL ground stations. This satellite is the latest in a series of Navy satellites, beginning with the first solar X-ray monitor in 1960.

The spin stabilized satellite was designed to measure solar X-rav emissions in six wavelength bands between 0.5 and 60 angstroms inclusive. Enhanced radiation in this range disrupts radio short-wave communications on the earth by changing the characteristics of the ionosphere.

Currently, communications forecasting efforts depend on indices of solar activity such as sunspot, flares, and solar radio noise. Since the solar X-ray outburst is the direct cause of the communication disturbance, the Solar Radiation Monitoring Satellite will provide a more reliable index of solar activity for communications predictions than any of the indirect observations made from the ground.

The Air Force Materials Development Program in 1965 placed special emphasis on glass fibers and developing new fibers such as carbon, carbides, boron, borides, beryllium, beryllides, nitrides and oxides. Composites of boron fibers reinforced epoxy systems were extensively evaluated because of the appreciable weight reductions possible.

A wide variety of polymers and ceramics were evaluated for ablative use. Considerable effort went into improving the oxidation resistance of the main four refractory metals - columbium, tantalum, molybdenum and tungsten. In the field of processing these metals, unusual techniques were developed for high speed extrusion using a uniquely instrumented 700-ton extrusion press.

Research and development effort in turbojet engines was expanded considerably during the year, placing four new aircraft engines into the initial stages of development. The C-5A engine development program benefited greatly from advanced engines which were started three years ago by two contractors. One competitive design resulted in superior performance and was selected for the final engine development.

A Memorandum of Understanding between the U.S. and the United Kingdom was agreed to on October 20, 1965, initiating a joint development program for a vertical takeoff aircraft lift engine.

Three competitive approaches were initiated in December 1965 for the development of a vectored thrust aircraft cruise engine. This advanced engine will have a vectoring device so that the thrust may be used for either lift or cruise.

The Advanced Strategic Aircraft Engine was in a design study phase during 1965. This engine will be designed to operate more efficiently over a wide range of speeds and altitudes.

COOPERATION WITH OTHER GOVERNMENT AGENCIES

General

Cooperation and program coordination with other governmental agencies, particularly NASA, in the space program continues to increase. Such efforts include joint research programs, the procurement of launch vehicles, the use of ranges and instrumentation facilities, the conduct of studies on technology and their potential application, and the assignment of highly trained personnel.

Aeronautics

An agreement was made in January 1965 that formalized the established practice between NASA and DOD for mutual support in aeronautical research and development. A current example of this practice is the XB-70 program. In May 1965 a Memorandum of Understanding established principles to utilize the Air Force XB-70 aircraft in support of the national supersonic transport program. Based on such principles, it is planned to conduct a joint USAF-NASA research program which will utilize the two XB-70 aircraft. The joint program will commence after the completion of the current Air Force program, expected to be completed by April 1966. After that time, under the joint effort, first priority will be given to the support of the NASA XB-70 flight research program. Provisions are made for mutual fiscal support.

In February 1965 the Army and NASA entered into an agreement for use and support of certain facilities owned by NASA and located at Ames Research Center. Under this agreement NASA is making available its 7x10 foot wind tunnel for use by the Army. In addition, the Army is participating in NASA's Low-Speed Aeronautical Research at that facility.

Secondary Payloads for Launch Vehicles

It is not unusual for a particular primary space experiment not to require the full space or weight carrying capacity of its assigned launch vehicle. Thus, opportunities are available to accommodate additional or secondary payloads. Recognizing the need to utilize the full capacity of NASA and DOD launch vehicles, particularly the large launch vehicles now becoming available, parallel procedures are being developed for this purpose and are being coordinated by NASA and DOD.

Reusable Launch Vehicle Technology

For the past several years consideration has been given to the desirability of a launch vehicle that could be recovered and reused. Although the advantages of such a vehicle have not been fully analyzed, it is necessary to support technologies that could contribute to such capability. A review and assessment of these technologies is being undertaken by an ad hoc subpanel of the Aeronautics and Astronautics Coordinating Board. This study will assist in evaluating the technical feasibility, potential operational applicability, and the advantages or limitations of the reusable launch vehicle concept.

Facilities Coordination

NASA and DOD are engaged in the construction of new facilities to meet their respective needs. In order to assure that neither agency constructs new facilities that would unnecessarily duplicate existing or planned new construction of the other agency, a formal procedure of coordination is conducted each year. Under these procedures, the proposed construction of facilities by each agency in FY 1967 have been jointly reviewed, compared, and coordinated.

Coordinated USAF/NASA Advanced Hydrogen-Oxygen Rocket Engine Program

The Air Force and NASA have throughout the year conducted exploratory development in this area of mutual interest to examine the problems associated with the program. The success of component investigations on two high pressure engine concepts has encouraged the USAF and NASA to consider the integration of these components into mockup engine demonstration programs.

In order to prevent duplication of efforts between DOD and NASA in this area, a joint Memorandum of Agreement was worked out. This agreement was a stepping stone from which a national program plan evolved. The plan contains each agency's planned activities in advanced hydrogen-oxygen rocket engine development through calendar year 1969.

DOD Participation in the GEMINI Program

The objective of the DOD interest in the GEMINI program is to raise the DOD experience level by evaluating techniques and equipment on NASA GEMINI flights. Results of the DOD experiments are expected to be important inputs to the Manned Orbiting Laboratory program. DOD participation also provided a mechanism for the timely flow of data from the NASA manned space flight activities to DOD agencies in 1965.

During 1965 DOD continued to refine thirteen Air Force and three Navy experiments. The need for one Air Force experiment requiring an astronaut to leave his space capsule was eliminated, but two DOD experiments were flown on GEMINI 4 and six on GEMINI 5. Action for flight hardware design, fabrication and integration into the GEMINI spacecraft on the remaining experiments proceeded on schedule.

Joint Navigation Satellite Committee

With the agreement of NASA, DOD, Department of Commerce, Department of Interior, Department of Treasury, and FAA, an interagency committee was established for the purpose of evaluating possible requirements and costs for alternative systems, including a new satellite system "to meet future needs in air and sea navigation, air and sea traffic control or coordination, air-sea emergency rescue, and related data transmission."

General Range Support by DOD for NASA Programs

The Defense Department is continuing to provide extensive service to NASA programs in the launch area at Cape Kennedy, Vandenburg Air Force Base, and at Eastern Test Range stations through the Caribbean and into the South Atlantic Ocean as far as South Africa. Worldwide Defense Department resources for range and network support and for planned and emergency recovery of astronauts are marshalled under the control of the DOD Manager for Manned Space Flight Support Operations in connection with GEMINI missions. Plans are being made for extension of the same type of support to the APOLLO program.

National Range Ships for APOLLO Support

Contracts have been let and modifications are under way to augment the National Range Ship Fleet to provide instrumented ship support of APOLLO. Three ships will cover insertion of the APOLLO spacecraft into earth orbit and injection of the spacecraft into a lunar trajectory. Two additional ships are being outfitted to assist in recovery of the spacecraft upon its return to earth.

Instrumented Aircraft Support for APOLLO

Eight C-135 aircraft are being modified to collect data and to provide communication with the APOLLO spacecraft during the critical period of departure from earth orbit in its journey toward the moon. The aircraft have been provided from Defense Department resources. The modification and operation of the aircraft will be managed by the Air Force.

Lunar Mapping

The DOD is currently engaged in 88 man years of work in support of Project APOLLO for NASA in the form of lunar maps, charts and other materials.

The work currently in progress is devoted in part to 1:2,000,000, 1:1,000,000 and 1:500,000 series maps and charts. In addition, work on larger scale maps and charts from RANGER Photography is under way. Other special map materials or data are being produced, such as orbital simulators, photometric studies, selenodetic control point generation, and earth landmark point identification data sheets (to check APOLLO navigation procedures in earth orbit).

Network Stations

Agreements have been made to transfer from the DOD to NASA the management responsibility for network stations at Kokee Park, Kauai, Hawaii; at Canton Island in the Pacific Ocean; and at Corpus Christi, Texas. This realignment was made in recognition of the predominant use of these stations in support of NASA programs.

General Support of NASA by Army

The Army performs a great variety of tasks for the support of NASA. The Corps of Engineers, in particular, has been responsible for the design and construction of NASA facilities at many locations. Other commands of the Army perform many specific tasks for NASA; examples are (1) development of an Omnidirectional Accellerometer by the Harry Diamond Laboratory, (2) Space Vehicle Destruction System at the Aberdeen Proving Ground, (3) Qualification and reliability testing of three additional GEMINI space suits at the Natick Laboratory, (4) Thermal control of spacecraft at Ft. Belvoir, (5) Extension of the state-of-the-art on foods for use in space at the Natick Laboratory.

Personnel Support of NASA

The practice of supporting NASA through the assignment of particularly qualified military officers was continued during this past year. A total of 237 officers are currently assigned throughout NASA; of these, 128 are Air Force, 80 are Army, 23 are Navy, and 6 are Marine officers. An additional 128 Air Force officers, with experience in planning and conduct of ballistic missile operations are to be assigned for further training to NASA's Mission Control Center at Houston, Texas. At the completion of their training they will be available for reassignment back to the Air Force for the MOL program.

DOD Support of FAA Programs

The Department of Defense and the Federal Aviation Agency joined efforts in the development of a single aircraft control radar system in the United States to be used for air defense as well as air traffic control. A cost-sharing and technical specifications agreement was reached and common radar data processors were put on procurement order in 1965.

ATOMIC ENERGY COMMISSION

CHAPTER V

INTRODUCTION

In June, 1965, the Atomic Energy Commission placed all of its space-related research and development activities under one Director in a newly established Division of Space Nuclear Systems. This Division divides into two main elements: the joint AEC-NASA office responsible for space nuclear rocket propulsion and isotopic thruster propulsion (Space Nuclear Propulsion Office -- SNPO), and the AEC office responsible for space nuclear electric propulsion and power (Space Electric Power Office -- SEPO).

A major advantage of the new organizational alignment is its establishment along lines similar to those of NASA, thus providing for improved communication and ease of coordination between the agencies in the power area.

NUCLEAR ROCKET PROPULSION SYSTEMS (ROVER PROGRAM)

Substantial progress was made in 1965 in developing the technology for using a nuclear rocket propulsion system for advanced space missions. The second of the series of NERVA Reactor Experimental (NRX) power reactors -- the NRX-A3 -- was successfully operated through three complete power cycles. During the first experiment on April 23, the reactor was operated for approximately eight minutes, three and one-half minutes of which were at full power of 1,100 thermal megawatts. On May 20, the same reactor was restarted and run for about 16 minutes, some 13 minutes of which were at full power. Following these two full-power experiments, the NRX-A3 was restarted for a second time on May 28 and operated in the low-to-medium power range for about 46 minutes. In each of the three tests, reactor performance was good, all test objectives were met, and excellent operational data were obtained.

In December, preparations for conducting the first NERVA Reactor Engine System Test (NRX/EST) planned in the NERVA technology development program were completed. The NRX/EST will be used to obtain information indicative of, and applicable to, an actual flight engine system. The NRX/EST comprises a flight-type reactor (the NRX-A4) mounted in an up-firing position on a test car modified to accommodate a close-coupled turbopump, and a regeneratively-cooled nozzle with a bleed port through which hot exhaust gas will be ducted to drive the turbine. The Engine System Test series will be followed in 1966 by groundbased experimental engine power tests in a down-firing engine test stand. Fabrication of the components for the first of these experimental engines was initiated during 1965.

To advance the KIWI-developed graphite reactor technology, which is also being utilized under Project NERVA, toward higher power and temperatures and longer operating durations, a series of KIWI-sized but higher-powered reactors, designated PHOEBUS, are being fabricated for ground testing. In June 1965, the first in the series of PHOEBUS reactor experiments was conducted on a reactor designated the PHOEBUS-1A. In the experiment, the reactor was run at full power and temperature for about 10-1/2 minutes. During startup and full power operation, reactor operation was smooth and stable. During the normal programmed shutdown from full power, however, the liquid hydrogen coolant-propellant supply in the test facility was exhausted and as a consequence the reactor core was damaged from overheating. This occurrence was not due to a reactor malfunction, but to the failure of the facility dewar level gauge which had been indicating a higher than actual residual of propellant. Steps to prevent the recurrence of this problem have been taken.

Work also progressed during 1965 on developing fuel elements, materials, hardware, and facilities which will permit the development and testing of a series of larger-diameter, higher-powered PHOEBUS-2 reactors. These ultimately will lead to the definition of a high-performance reactor design suitable for inclusion in a high-thrust engine system.

In addition to the reactor experiments conducted during 1965 to advance the state of graphite reactor and engine system technology, a safety experiment known as the KIWI-Transient-Nuclear-Test also was conducted (January 12, 1965) to determine the accuracy of theoretical techniques developed for predicting the response of a graphite reactor to very large and rapid insertions of reactivity. In the experiment, a KIWI-sized reactor (1,000 thermal megawatts) was deliberately destroyed by subjecting it to a very fast power increase. The results of the test were in good agreement with predictions. The experiment demonstrated that even under the most extreme launch accident conditions, the safety of personnel both on and off-site could be readily assured.

ISOTOPIC THRUSTERS

The Isotopic Thruster Systems are low-thrust rocket engines using the thermal energy generated by isotope decay to heat hydrogen or other propellants to high temperatures prior to expulsion through a nozzle to produce thrust. These small rocket engines would have total thermal powers ranging from a few watts to on the order of five kilowatts and would be capable of producing thrusts ranging from a few millipounds to a quarter of a pound at a specific impulse of up to 700-800 seconds with hydrogen. Based upon these performance capabilities, Isotopic Thruster Systems appear to be attractive as an upper stage for missions such as deep space probes, propelling payloads from low earth orbit to high earth orbits, for low thrust orbital operations, and for space vehicle attitude control systems.

Effort is presently concentrated on the development of high-temperature radioisotope fuel forms, fuel encapsulating techniques, and thruster technology.

SPACE REACTOR POWER SYSTEMS

SNAP-10A Flight Test (SNAPSHOT-I)

The nation's space and atomic energy program made history with the successful launch (on April 3, 1965) and operation of SNAPSHOT-I -- the flight test of the SNAP-10A reactor -- into greater than a 4,000-year, 800-mile high Polar orbit. The 500-watt reactor was started up after it was in a stable orbit, and operated for 43 days -- until May 16 -- producing more than 500,000 watt-hours of electricity.

All systems operated satisfactorily throughout the critical early stages of the flight, and all performance data recorded during the test confirmed design predictions and ground test experience.

To determine the cause of the reactor's premature cessation of operation, various ground tests were made in an attempt to simulate the failure, and telemetry data acquired from the satellite during the reactor's operation were re-analyzed. The most probable cause is the sequential failure of electronic components in the space-carft which generated spurious signals which, in turn, initiated the reactor shutdown.

SNAP-10A Ground Tests

The SNAP-10A nuclear ground test system (the FS-3) -- a flight-qualified copy of the SNAPSHOT-I orbital test system -- was put into operation on the ground, under simulated space conditions, on January 22, 1965. By the end of the year, this "twin" of the flight system had operated continuously for more than 340 days at design conditions.

SNAP-8

As a result of budgetary decisions, the NASA portion of the joint AEC-NASA SNAP-8 program entered a phase-out program early in 1965. NASA is continuing its development work on the power conversion system (PCS) to obtain as much test time as possible within the FY 1965 funds available, and SNAP-8 reactor work is continuing to be pursued by the AEC.

On April 15, the SNAP-8 Experimental Reactor -- the first power reactor of the SNAP-8 series -- completed its scheduled program of test operation and was shut down. During this program, the reactor was operated at or above 400 thermal kilowatts and 1,300°F coolant outlet temperature for 366 days, 100 days of which were at 600 thermal kilowatts and 1,300°F. From September 18, 1964 until final shutdown 209 days later, the reactor demonstrated uninterrupted operation.

Testing of a non-nuclear version of the second power reactor in the SNAP-8 series -- the SNAP-8 Developmental Reactor Mockup -- was completed in July 1965. The nuclear version -- the SNAP-8 Developmental Reactor -- is now being fabricated and is scheduled to achieve initial criticality in the Spring of 1966.

RADIOISOTOPE GENERATORS FOR SPACE APPLICATIONS

The 25-watt SNAP-11 thermoelectric generator will be fueled with the Curium-242 isotope in mid-1966. Electrically-heated models will be delivered to NASA's Jet Propulsion Laboratory and Houston Manned Spacecraft Center for environmental and compatibility testing. The SURVEYOR program for which the generator was orginally developed does not now plan on using such a device since the present solar panels power system appears suitable for meeting all mission needs.

In February 1965, two electrically-heated 30-watt SNAP-19 generators were delivered to NASA's Goddard Space Flight Center where they are undergoing tests based on NIMBUS-B advanced experimental weather satellite specifications.

At NASA's request, the AEC in 1965 selected an industrial contractor to initiate the development of a 50-watt Plutonium-238 fueled SNAP-27 thermoelectric power supply, designed for intact re-entry into the earth's atmosphere from orbit, for a number of lunar surface applications, including powering a package of experiments left on the moon by the astronauts.

The AEC also initiated studies during 1965: (1) to provide a higher power capability in a single 250-300 watt Plutonium-238 fueled power supply for use in orbital and deep space missions for NASA; (2) to prepare the preliminary engineering design of a polonium-fueled thermoelectric generator for the Department of Defense; (3) to prepare preliminary engineering designs of a kilowatt-sized plutonium- or polonium-fueled thermoelectric power system for Apollo Applications Systems (AAS) for NASA; and (4) to investigate the use of Curium-244, Polonium-210, and Plutonium-238 as heat sources for subsystems of manned space electric power systems which can provide 1-10 kilowatts of electricity and employ either thermoelectric, thermionic, or dynamic power conversion systems.

SPACE-DIRECTED ADVANCED REACTOR TECHNOLOGY DEVELOPMENT

SNAP-50

The SNAP-50/SPUR (Space Power Unit Reactor) program to develop a 300 to 1,000 electrical kilotwatt nuclear-electric space power plant was terminated in June 1965. That work has been redirected to a longer-range advanced technology development effort rather than a major hardware development effort. The industrial laboratory where the SNAP-50 reactor and power plant integration work has been centered was shut down, and over-all system design, reactor design, and materials research work in conjunction with high power systems were transferred to an AEC laboratory. Two industrial contractors are continuing developmental work on turboalternators, condensers, boilers, and other boiling-potassium power conversion equipment.

Compact Thermoelectric Converter

Competitive first-phase programs were initiated in June with two undustrial contractors on two concepts of a compact space thermoelectric power converter of modular form which could be used to develop from 1 to 20 electrical kilowatts and can be mated with either zirconium-uranium hydride reactors or radioisotopes as the heat source. Phase I, an engineering study, of the 3-5 year over-all program is scheduled for completion in early 1966. Later phases will cover module development, module qualification, and prototype fabrication and qualification.

Advanced Space Reactor Concepts

Two of the advanced reactor concepts presently under investigation which have potential space applications and thus are now aligned under the management of other AEC space-related research and development activities, are the Medium Power Reactor Experiment (MPRE) and the Advanced High Temperature Gas Cooled Reactor (710) project. The MPRE at Oak Ridge, Tennessee, is exploring the feasibility of a direct cycle, boiling potassium, fast reactor to develop large amounts of electrical power for possible use on space missions. In 1965, mockup experiments were conducted to obtain data necessary for the design of the reactor experiment and its facility, and in-pile (in-reactor) and out-of-pile testing of uranium dioxide fuel pellets was initiated to determine their integrity and stability under irradiation. The 710 reactor program being carried out for the AEC by an industrial contractor is aimed at developing and demonstrating refractory metal reactor technology for use in an inert gas-cooled reactor system capable of generating electric power in space. During 1965, effort was concentrated on developing and testing gas-cooled fuel element samples and such non-nuclear reactor components as actuators and pumps.

SPACE NUCLEAR SAFETY ACTIVITIES

Two major series of safety experiments were carried out in 1965 on a modified SNAP-10A type reactor to obtain data on temperature, peak power, and energy release in regions previously unexplored.

SATELLITE-BASED DETECTION OF NUCLEAR EXPLOSIONS IN SPACE

A third new and improved pair of AEC-instrumented nuclear test detection satellites were launched in tandem from one ATLAS-AGENA rocket in mid-July to join the four other orbiting and still functioning systems which were launched in pairs in October 1963 and July 1964. The new twin detection satellites contain instruments for detecting radiations from nuclear explosions in space and improved sensors and information processing equipment which are better able than their predecessors to discriminate between natural radiation and man-made radiation in space.

In addition to watching for nuclear explosions in space, the satellites are measuring X-ray emissions from the sun as solar activity builds toward a new maximum in 1968. Measurements of solar particles, including their interaction with the earth's magnetic field, are also being made. The new satellites and the four still operating are expected to make an important contribution to information on the sun's activity cycle, in addition to performing their detection role.

The AEC is now preparing instrumentation that incorporates improvements based on past experience for a satellite launch in 1966.

DEPARTMENT OF STATE

CHAPTER VI

INTRODUCTION

The Department welcomed the President's decision in 1965 to make greater use of our astronauts in telling abroad the story of the U. S. space effort. These brave and forthright men have done more in a few months to strengthen bonds of friendship between the United States and the many countries they have visited than could have been achieved in as many years by more conventional diplomacy.

The President's decision to send a top-level commission to Europe early in 1966 to consult with governments of Europe "wishing to participate in the joint exploration of space" promises to open a new chapter in United States space cooperation with other nations. The President's initiative, and the transatlantic consultations during the first months of 1966 resulting therefrom, are expected to stimulate governmental, scientific, and industrial experts in Europe to think about ways in which their space aspirations can be better realized through closer collaboration with the United States, for the benefit of all mankind. This type of cooperation among the European nations themselves is very much in line with U.S. foreign policy objectives.

The Committee reaffirmed the recommendations contained in its 1964 report, on which the General Assembly had not yet taken action, and recommended that the Legal Subcommittee resume its work in the first part of 1966. The Committee also decided that a working group established to study the desirability, organization, and objectives of a 1967 international conference or meeting on the exploration and peaceful uses of outer space should meet in January 1966. The Committee noted with appreciation the reportsof the International Telecommunication Union and the World Meteorological Organization in the field of outer space.

At the Twentieth Session of the General Assembly, the U.S. Ambassador to the United Nations opened the First (Political) Committee's discussion of international cooperation in the peaceful uses of outer space with a major address on December 18. He emphasized cooperative activities of direct interest to the developing countries and the Member States which do not have large space programs, such as weather and communications satellite programs, the U.S. invitation to foreign scientists to propose experiments for inclusion on NASA satellites, joint sounding-rocket and satellite-launching programs, distribution of Ranger photographs of the moon to scientists in other countries for professional analysis, and educational opportunities in the United States. The Ambassador stressed the need to carry out space programs in an open and generous manner and invited his colleagues to inform him if they wished to visit Cape Kennedy or other NASA centers. He specifically invited all nations represented in the U.N. to examine the American space program for projects, interesting to them as well as to the United States, which could be carried out cooperatively on a realistic and manageable basis. Recalling his suggestion of September 23 that the United Nations begin work on a comprehensive treaty on the exploration of celestial bodies, he said that the United States plans to present a definite proposal as to the contents of such a treaty.

On December 20, the First Committee adopted a resolution based on the report of the Space Committee and co-sponsored by thirteen members of that Committee, including the United States. The resolution was adopted unanimously in a plenary session of the Assembly on December 21. It recognized that the benefits of space exploration can be most widely enjoyed if Member States support the widest possible exchange of information and promote international cooperation; asked member States to cooperate with the Space Committee's program; urged the Space Committee to continue work on the assistance and return and liability agreements; endorsed the Space Committee's recommendations on scientific and technical cooperation; accorded U.N. sponsorship to the International Equatorial Sounding-Rocket Launching Facility at Thumba, India; and requested the Committee to consider suggestions for programs of education and training in the peaceful uses of outer space to assist the developing countries.

The Department, through its scientific attaches and scientific affairs officers at embassies abroad, was pleased to forward promptly for foreign scientific appraisal the historic television photographs of the Martian surface taken in July 1965 by the MARINER IV spacecraft. Copies of selected photographs were also forwarded to our ambassadors for presentation purposes as soon as they were available. Activities such as these help make clear our genuine desire to share with the world the knowledge we gain from space exploration.

ACTIVITIES WITHIN THE UNITED NATIONS

On September 23, 1965, in his speech during the general debate of the U.N. General Assembly, Ambassador Goldberg stated that in accordance with ground rules laid down by the General Assembly, U.S. space activities had been, and would continue to be, non-aggressive, peaceful, and beneficial in character. He suggested that the United Nations, in order to keep pace with technical progress in space, begin work on a comprehensive treaty on the exploration of celestial bodies.

The Legal Subcommittee of the U.N. Committee on the Peaceful Uses of Outer Space met in New York from September 20 to October 1, 1965. The purpose of the meeting was to continue consideration of draft international agreements on: (1) assistance to and return of astronauts and space objects, and (2) liability for damage caused by objects launched into outer space. On the question of liability, the United States and Hungary introduced revised texts, and some area of agreement evolved among members of the Committee. Due to the complexity of the subject, however, much work remains to be done. On the question of assistance to and return of astronauts and space objects, the Subcommittee regrettably failed to reach an agreed text.

The Committee on the Peaceful Uses of Outer Space met in New York from October 5 to 8, 1965. Most of the session was devoted to a general debate in which new light was cast on the space programs and activities of member states. In his general statement, the United States Representative concentrated on various U.S. cooperative space efforts.

TRACKING NETWORKS

NASA Facilities

Government-to-Government agreements by exchange of notes are in existence with the following countries covering the foreign portion of NASA's global tracking network: Australia, Canada, Chile, Ecuador, Malagasy Republic, Mexico, Nigeria, Peru, South Africa, Spain, and the United Kingdom. These facilities consist of nine stations in support of the manned space flight program, an eight-station tracking and telemetry network for scientific satellites, and deep-space antennae at four locations around the world. These are in addition to the U.S. Air Force's Eastern Test Range facilities, with installations as far away as the Canary Islands and South Africa, which are used by NASA as well.

During the past year the United States, through its embassies abroad, negotiated extensions of agreements with Ecuador, Mexico, and the United Kingdom. In addition, modifications of existing agreements have been or are being negotiated with Australia, Malagasy Republic, Spain, and the United Kingdom in preparation both for Project APOLLO and for new or expanding scientific satellite programs.

Optical Tracking Stations

An exchange of letters between the American Ambassador at Addis Ababa, on behalf of the Smithsonian Astrophysical Observatory, Cambridge, Mass., and the Haile Selassie I University was effected October 13, 1965, covering the establishment and operation of an optical (Baker-Nunn) tracking station near Debre Zeit, Ethiopia. This agreement was reached after protracted negotiations commencing in July, 1964. The need for the Ethiopian station arose because of the necessity to relocate for technical reasons the camera now at Shiraz, Iran. It will be one of nine SAO Baker-Nunn installations outside the United States.

Cooperation with ESRO

In October 1965 the House of Representatives approved a bill (H.R. 8210) which would enable the President to apply the provisions of the International Organizations Immunities Act to the European Space Research Organization (ESRO). The significance of this action lies in the fact that ESRO is seeking to establish a satellite telemetry/command station near Fairbanks, Alaska, as a part of its planned network in support of ESRO scientific satellites. While the station will be manned primarily by U.S. contractor personnel, ESRO desires to obtain for its non-American personnel privileges and immunities on the same order as those customarily extended abroad to NASA station personnel, as well as duty-free entry privileges with regard to station equipment and supplies. An amendment of the International Organizations Immunities Act, as contemplated by H. R. 8210, would satisfy ESRO's request.

The ESRO station in Alaska should be in operation by the end of 1966 in order to be available for the first of two launchings of ESRO satellites which are scheduled for 1967 under the terms of a cooperative agreement between ESRO and NASA. The Administration therefore urges the early consideration of S. 2130 (the companion bill now before the Senate) in order that action on this legislation may be completed during the current session of Congress.

CONTINGENCY RECOVERY OF ASTRONAUTS

The Department of State and its overseas posts maintained a state of alert throughout each of the manned GEMINI flights -- the three-orbital GEMINI 3 flight in March, the "space walk" flight (GEMINI 4) in June, the eight-day GEMINI 5 flight in August, and rendezvous and fourteen-day flights (GEMINI 6 and 7) in December. Prior to each mission a GEMINI Task Force, consisting of watch officers from each regional bureau, as well as senior representatives of the Office of Legal Adviser, International Scientific and Technological Affairs, and the Office of Politico-Military Affairs, was assembled under the direction of a Senior Control Officer, normally the Deputy Under Secretary for Political Affairs. The principal purpose of the Task Force is to enable the Department, on a moment's notice in event of a premature landing or other emergency, to call upon the appropriate posts abroad to arrange through the respective host governments for such assistance as is indicated by the nature of the emergency. Another important task is to assist in the maintenance of clear communications channels between the space capsule and ground stations by alerting posts whenever interference on GEMINI frequencies was reported in any part of the world. When necessary, posts were instructed to request through their host governments the silencing of potentially harmful interference. To date there has been no instance of radio interference harmful to a GEMINI mission, thanks to excellent cooperation of governments on both sides of the Iron Curtain.

Similarly, principal Foreign Service posts between 32 degrees north and 32 degrees south latitudes are under instruction to maintain an increased alert during manned space missions. Each such post has an officer whose duty it is to keep abreast of space flight planning for every mission as it evolves. To reduce communications delays between the Department and the field to an absolute minimum the Communications Watch Officer has on hand during each mission a number of perforated tapes containing various types of emergency messages, so that only the blanks need be completed.

Prior to each GEMINI mission the Department through embassies abroad facilitates the positioning of Air Force SAR (Search and Rescue) Units at strategic locations around the globe. To the maximum extent possible overflight clearances are obtained in advance from countries through which SAR Units might have to fly in event of emergency.

ASTRONAUT TRAVEL ABROAD

Now that the United States has passed through the early, critical stages of its manned space flight program, the President has decided to make use of our astronauts from time to time to carry abroad the message that the U.S. space program is devoted solely to the cause of peace.

On June 18, 1965 a premier showing of the NASA color film of the GEMINI 4 flight, "Walk in Space," was held in the Department of State auditorium for members of the Diplomatic Corps and their families. Following narration of the film by GEMINI 4 Astronauts McDivitt and White, the President announced his plan to send the Vice President, accompanied by the two astronauts to the Paris Air Show then in progress. Within eight hours, the Vice President and his party were aboard a Presidential aircraft bound for Paris.

The party was greeted by large crowds upon arrival at Le Bourget Airport. The first day's activities included a large press conference for the astronauts at the airport and a reception that evening for 3,000 persons hosted by the American Ambassador. The Vice President and the astronauts visited the Air Show and accompanied by the Ambassador called on President de Gaulle.

Encouraged by the overwhelming success of the McDivitt-White visit to Paris, the President immediately following the safe completion of the eight-day GEMINI 5 mission asked Astronauts Cooper and Conrad, and their wives, to undertake a more ambitious good-will trip abroad. The two-week itinerary (September 15-29) was worked out with the assistance of the Department of State and included visits to Athens, Thessaloniki, Izmir, Istanbul, Ankara, Addis Ababa, Tananarive, Nairobi, Lagos, four cities in the interior of Nigeria, and Las Palmas, Canary Islands. Again, transportatation was via Presidential aircraft.

The entire trip was successful in presenting, through the astronauts, our country's willingness to share with the world our knowledge gained from space exploration. The first major item on the astronauts' schedule was a presentation at the International Astronautical Federation Congress, Athens, where eminent scientists and engineers from all over the world were in attendance. Other highlights of the trip included meetings with the Soviet cosmonauts at Athens and a visit to the NASA tracking station at Kano, Nigeria. At Addis Ababa the astronauts met with the U.N. Economic Commission on Africa and the Organization of African Unity.

The astronauts were received by the respective chiefs of state in five of the seven countries visited. In Nigeria they were received by the Prime Minister in the absence of the President. At Las Palmas they were received by the Spanish Governor. The astronauts were welcomed by large and enthusiastic crowds. In addition to numerous television appearances and crowded press conferences, the astronauts spoke before countless audiences which included scientists, teachers, high government officials, and ranking diplomats. Press, radio and television coverage was excellent throughout the trip.

During the first three weeks of October 1965, former Astronaut John W. Glenn, Jr. visited the following European cities as special emissary of the President: Frankfurt, Munich, Bonn, Bremen, Berlin, Hamburg, London, Amsterdam, The Hague, Rotterdam, Genoa, Rome, Naples, Madrid, and Lisbon. The Glenn party traveled by commercial aircraft. Plans and arrangements for the trip were worked out jointly by NASA, the Department of State, and USIA, on the basis of recommendations received from the American embassies in the six countries visited. A full schedule was built around lectures and appearances before scientific and technical groups. However, it included extensive public exposure as well as calls on government dignitaries at each stop. Col. Glenn carried special words of greeting from the President to Chancellor Erhard (Bonn) and Mayor Brandt (Berlin). An unqualified success from beginning to end, the Glenn trip gave a real boost to public and official support in Western Europe for the U.S. space effort.

These trips have demonstrated beyond question that the United States possesses in its astronauts a foreign policy asset of the first order. Peoples in all parts of the globe should have the opportunity of meeting them, to the extent this can be done without interfering with their primary mission of space exploration and experimentation.

KOREAN PRESIDENT VISITS CAPE KENNEDY

On May 22, during his State Visit to the United States, his Excellency Chung Hee Park, President of Korea, visited Cape Kennedy and made a four-hour tour of NASA facilities here. The tour included a briefing on Project APOLLO and, by coincidence, a down-range firing of an APOLLO "boilerplate" for the purpose of testing the heat shield at reentry velocity.

COOPERATION WITH DEPARTMENT OF DEFENSE

The Department of State worked closely with the Department of Defense during 1965 on international aspects of the Initial Defense Communications Satellite Program (IDCSP) and the Manned Orbiting Laboratory (MOL) Project.

COMMUNICATIONS VIA SATELLITES

An important milestone was achieved by the international communications satellite consortium with the successful launching of its first earth satellite on April 6, 1965. The EARLY BIRD satellite, which is in a synchronous equatorial orbit over the Atlantic Ocean, is equipped with 240 telephone channels. Since June 28, 1965, the satellite has been used to provide public services between Europe and North America. Commercial operations to date through EARLY BIRD gave a high degree of assurance that plans for the provision of global coverage can be achieved.

In meeting certain telecommunications requirements of Project APOLLO, the consortium will have excess space segment capacity available which can be used to serve other areas of the world a year in advance of the original objective of having a global system in being by the end of 1967. The launching in 1966 of two synchronous satellites for Project APOLLO will permit service to be extended to some countries in Latin America, Africa, and the Far East by the latter part of the year.

The Department of State, with the assistance of the Communications Satellite Corporation, was active in 1965 in encouraging states members of the International Telecommunication Union to become parties to the Agreement Establishing Interim Arrangements for a Global Commercial Communication Satellite System. On August 20, 1964, eleven countries initially signed the Agreement, including the United States, and by the end of 1964, this membership had grown to 19. During 1965, participation was further increased from 19 to 48. Most of the geographic areas of the world are now represented in the consortium, and it is anticipated that several additional countries will decide to participate in this unique international organization in the coming months. All of the countries party to the main intergovernmental Agreement have also designated an entity, either private or public, to participate in the consortium and have signed the Special Agreement. Furthermore, pursuant to Article 14 of the Special Agreement, a Supplementary Agreement on Arbitration, was negotiated and opened for signature on June 4, 1965. To date, 37 countries have signed the Supplementary Agreement which will enter into force when all parties to the intergovernmental Agreement have signed it.

The Intergovernmental Agreement established an Interim Communications Satellite Committee having responsibility for the design, development, construction, establishment, maintenance and operation of the space segment for a global communications satellite system. This Committee meets regularly every month on matters involving the affairs of the consortium.

NATIONAL SCIENCE FOUNDATION

CHAPTER VII

INTRODUCTION

The National Science Foundation supports basic research in the sciences, promotes improved science education in the United States, provides assistance in facilitating better exchange of scientific information, and carries out associated activities. Most of the work supported by the National Science Foundation is carried on at colleges, universities, and nonprofit institutions in the United States.

The Foundation also has special responsibilities with respect to certain national research centers and national research programs. It is in the latter areas that National Science Foundation activities are more closely associated with those of the overall national space effort.

The National Radio Astronomy Observatory (West Virginia)

The 140-foot precision radio telescope, which has been under construction for several years, was dedicated on October 13. It has been in full operation since July. A new emission line in the spectrum of hydrogen gas was discovered with it soon after it was completed.

The 300-foot telescope, the world's largest movable parabolic radio antenna, was used regularly during 1965 by staff and visitors for various research programs, including observations of the distribution of hydrogen in our own galaxy as well as in other galaxies. Many measurements were also made of the polarization of radiation from discrete sources.

A 36-foot high-precision radio telescope designed to operate at millimeter wavelengths is nearing completion. It will be located at the Kitt Peak National Observatory in Arizona, where the altitude and the dry climate are favorable for observation of these short wavelengths.

The Kitt Peak National Observatory (Arizona)

Designs for a 150-inch reflecting telescope at the Kitt Peak site are nearing completion. A fused quartz blank for the telescope mirror is being manufactured by the General Electric Company. One new telescope went into operation during the year: it is a 50-inch highly automated reflector, which can be operated either by manual control from the site or by remote control from Tucson headquarters.

The 84-inch stellar telescope was used throughout the year by staff and visitors, as were several smaller telescopes. An additional 36-inch reflector is being built to fill the ever-increasing demand by visitors for observing time on telescopes of moderate aperture.

The 60-inch solar telescope continued in demand for both daytime and night observations. It was used for a wide range of studies including a determination of the abundance of the chemical elements lithium and boron in the sun's atmosphere. During the appearance in October of the unexpected bright comet Ikeya-Seki about 60 spectrographic plates were obtained by this instrument at the highest dispersion ever used for cometary spectra; these spectrograms showed that the comet contained gases of sodium, iron, and calcium.

In the Space Division the Aerobee rocket program continued with three successful launchings during the year, one of which carried a camera which photographed the light of the sun in X-rays being emitted by it. Several theoretical investigations of planetary atmospheres are also being carried out.

Cerro Tololo Inter-American Observatory (Chile)

A 60-inch and a 36-inch telescope for this new observatory are under construction and are expected to be delivered in Chile in January 1966. In the meantime the domes to house these instruments are under construction. Photoelectric observations with an existing 16-inch telescope have continued.

The E. O. Hulburt Center for Space Research (Washington, D. C.)

Participation of university faculty members and graduate students in rocket and satellite astronomy at the Naval Research Laboratory is made possible by continued NSF support.

The International Years of the Quiet Sun (IQSY)

The second half of IQSY occurred in 1965. It is a coordinated effort to study the geophysical and interplanetary environment of the earth during the period of sunspot minimum. Federal coordinator for this national research program is the National Science Foundation.

The program for IQSY consists of projects in meteorology, geomagnetism, aurora, airglow, ionospheric physics, solar radio astronomy, solar activity, the interplanetary medium, cosmic rays, trapped particles, and aeronomy.

It has been established in retrospect that solar minimum actually occurred during the first part of 1964. The minimum of the sunspot cycle is in reality the low point between two overlapping cycles which can be distinguished by the magnetic polarity of the spots and their latitude on the sun. Thus, for example, the first spot of the new cycle was already observed in August 1963, while spots of the old cycle were still evident during the spring of 1965. In addition to the number of sunspots, other optical and radio astronomy indices also indicated a minimum in late spring of 1964. During this interval, the sun was also extremely quiet as observed in the X-ray region from satellites.

Activity on the earth that is presumably solar-related has not been in exact phase with the solar activity indices just described. Geomagnetically disturbed days can exist without any obvious signs of solar activity, although the general level of geomagnetic activity is now rising as the sun becomes more active following the minimum. Records of cosmic rays, ionospheric structure, and whistlers which travel through the magnetosphere, have in general responded as expected to the decline and subsequent rise in solar activity. However, the interaction is a complex one and not all indices move in unison. Detailed studies of data acquired during intervals of especially high or especially low activity during the IQSY are still to be undertaken.

Two special IQSY expeditions were undertaken during the year. The Equatorial Balloon Expedition involved launching high altitude balloons in India for about ten universities, primarily for cosmic ray studies near the geomagnetic equator. The expedition was managed by the National Center for Atmospheric Research. The second expedition was to observe the solar eclipse of May 30, 1965, both from the astronomical and atmospheric sciences point of view. The ground-based activities of this expedition were coordinated by the Kitt Peak National Observatory and were centered on two islands in the South Pacific--the atoll of Manuae in the Cook Islands and the island of Bellingshausen in the Society Island group. Although the group on Manuae was clouded out, those on Bellingshausen were able to make useful observations. In addition to these ground-based groups, four jet aircraft equipped with optical windows and loaded with spectrographs and other optical instruments flew at altitudes up to 42,000 feet, rising above the clouds and extending the duration of totality by chasing the shadow. For the observers in one of these aircraft, totality lasted more than nine minutes, the longest interval of total eclipse ever achieved. While the data secured from these expeditions have not yet been completely evaluated, it is clear that we now have an exciting new approach to use for such observations.

DEPARTMENT OF COMMERCE

CHAPTER VIII

INTRODUCTION

A significant number of the activities of the Department of Commerce contribute to the Nation's space program. Organizationally, the major contributors are the National Bureau of Standards, the Environmental Science Services Administration, and the Office of the Under Secretary for Transportation.

ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION

Pursuant to the President's Reorganization Plan No. 2 of 1965, the Weather Bureau, the Coast and Geodetic Survey, and the Central Radio Propagation Laboratory of the National Bureau of Standards were merged into the Environmental Science Services Administration (ESSA). The establishment of ESSA, accomplished during the latter part of 1965, has brought all Department of Commerce activity in the environmental sciences under a single office. The Administration serves as the focus of the Department's efforts to describe, understand, and predict the size and shape of the earth, the state of the oceans, the atmosphere, and the space environment.

HIGHLIGHTS OF 1965

The TIROS IX meteorological satellite provided the first daily weather observations of the entire sunlit globe, thereby achieving a goal that has spurred meteorologists for 300 years. Meanwhile, TIROS VII and VIII completed two and one-half and two years of useful operational life, respectively, far exceeding the lifetime of any previous meteorological satellite. EXPLORER XX continued to provide highly significant ionospheric sounding data throughout 1965. Triangulation with the ECHO satellites provided a higher degree of geodetic control for the country. A field evaluation of the Navy Satellite Navigation System demonstrated that this system is the best available operational means for navigational control of oceanographic survey work.

Very extensive ground-based experiments and observatories provided data on the ionosphere, the outer atmosphere, and beyond, to support and complement experiments from space vehicles.

A mathematical model was developed which permits estimates of the geomagnetic field to the limits of the magnetosphere.

Meteorological Satellites

The year 1965 saw an historic fulfillment of the meteorologist's oldest dream: observation of the weather over the entire world, each day. Beginning with a cooperative effort by 10 observing stations in central Europe more than 300 years ago, a succession of technological advances and international agreements has brought this dream steadily closer to reality. The last step--bringing the weather of remote oceans and inaccessible land areas under daily observation--could be achieved only with the development of artificial earth satellites.

On January 22, 1965, the National Aeronautics and Space Administration launched TIROS IX, the tenth in its series of experimental meteorological satellites. For the next two months, the satellite had the capability for producing television pictures which, during the course of each day, could show the entire sunlit portion of the earth (omitting only the darkened north polar region). Meteorologists of the National Weather Satellite Center (now the NESC) assembled and analyzed each group of pictures, and transmitted schematic cloud maps to weather forecasting stations throughout the United States and overseas.

The daily worldwide coverage was made possible by the new wheel design of TIROS IX, and its launch into a near-polar orbit. As the cylindrical satellite rolls along its path, the cameras, mounted in its rim and looking downward once during each revolution, can photograph the earth from any part of the orbit. The special launch maneuvers required to rotate the satellite into operational attitude were executed flawlessly. The horizon sensors used to trigger the cameras have worked perfectly, as have the magnetic orientation coils which control the attitude and spin rate of the satellite.

The successful operation of these previously untested components confirmed the feasibility of the wheel design, and allowed the Satellite Center to proceed rapidly with its plans for developing the TIROS Operational Satellite (TOS) system. The TOS system, scheduled to be established and operating in early 1966, will carry further the promise of TIROS IX by providing daily, worldwide weather observations on a continuing year-round operational basis.

TIROS X

TIROS X, the first meteorological satellite to be completely funded by the Department of Commerce, was launched by NASA into a near-polar sun-synchronous orbit on July 2, 1965. This standard TIROS satellite was originally scheduled for a normal TIROS orbit in which it could have acquired photographs of only 20 percent of the earth's surface every 24 hours. By changing to a near-polar orbit with its cameras viewing parallel to the spin axis, it has been possible to obtain three times the photographic coverage without modifying the spacecraft or the launch vehicle. TIROS X has been used extensively for tropical storm watch and numerous other projects.

TIROS VII and TIROS VIII

On December 31, 1965, TIROS VII completed more than two and one-half years of successful operation. This satellite, launched on June 19, 1963, had two vidicon cameras in operation until October 19, 1965, when one camera failed. The remaining camera is still providing excellent data. The medium-resolution infrared radiometer was deactivated on June 18. TIROS VIII, launched December 21, 1963, also passed the two-year mark with its single recording vidicon camera furnishing good-to-excellent photographs. These records of long-term operation, and the successful operation of TIROS IX, confirm the dependability of the TIROS spacecraft as the basic satellite for the TOS system.

TIROS IX and X, in near-polar orbits, furnished the main support to operational and research projects during 1965. TIROS VII and VIII were used primarily as back-up to the other satellites. All were programmed as necessary to take cloud pictures of specific areas at specified times to furnish the weather information requested.

Keeping a watch on tropical storms was one of the main operational projects of the year. All of the TIROS satellites were programmed to assure continuous surveillance of areas of tropical storm formation. When such a storm was identified, it was tracked day-by-day until it dissipated. Meteorologically-coded advisories or plain-language messages were sent to the weather services of all countries likely to be affected by the storm. The satellites were instrumental in the initial discovery of storms known to have occurred in the tropics during 1965.

In addition to the above, many special projects, operations, and organizations requested and received direct support from TIROS satellites in 1965, including U. S. - Canadian ice reconnaissance studies, the International Indian Ocean Expedition, ice reconnaissance studies of northern Japan, and launch and recovery support for GEMINI operations.

Centralized Receipt and Processing of Satellite Data

Satellite data are now processed centrally at the NESC in Suitland, Md. The picture signals received at the two Command and Data Acquisition (CDA) stations near Fairbanks, Alaska, and Wallops Station, Va., are now retransmitted directly to the processing center at NESC. Here the signals are reconstituted on kinescopes and photographed. The photographs are then analyzed, and nephanalyses (cloud maps) are prepared. These are the nephanalyses transmitted by radiofacsimile in pictorial form, and by radioteletypewriter in weather code form to users all over the world. Processing of all pictures at the Suitland Center instead of at the CDA stations has decreased by 50 to 60 percent the average lapse between the time the signals are received on the ground and the time the final product is ready for transmission to the users. The preparation time will be decreased further when the nephanalyses are prepared directly from the analog signals by high speed computer. Operational computer processing of the picture signals is planned for implementation during 1966.

Research and Development Programs

The Meteorological Satellite Laboratory, as the research aim of NESC, seeks: (1) to extract from the satellite data the maximum possible amount of weather information; and (2) to find new or improved ways to obtain by satellites information which will contribute toward improvement of the various services provided by the Weather Bureau and by ESSA. The Laboratory carries out analytical studies, research investigations, and experimental programs to achieve these goals.

Work continued during 1965 on the interpretation and analysis of the cloud pictures and infrared data received from the satellites. These data observed from space are used to study atmospheric motions, the heat balance of the atmosphere, and the structure and development of storms. The results of the studies carried on by the Meteorological Satellite Laboratory are expected to lead to increased understanding of atmospheric processes, and to improved methods for forecasting weather. Among the more than 50 individual investigations of the laboratory, several are of particular interest:

a. a method developed for estimating maximum wind speeds in hurricanes using the satellite photographs as the sole source of data. This method was tested in 1964 and used throughout 1965 with excellent results.

b. a method for improving numerical weather prediction models by the use of satellite data was tested during 1965. The overall reduction of error between numerical forecasts made without satellite data input and those made with satellite data was 5.4 percent for the six cases tested.

c. the satellite infrared spectrometer, an instrument designed to measure the vertical temperature structure of the atmosphere from satellite altitudes, was successfully tested in 1964 on a balloon flying at 100,000 feet. A flight model to be tested on NIMBUS B in 1967 is under construction.

d. a special spectrograph designed to measure cloud heights from satellites was successfully tested on the GEMINI 5 spaceflight. This spectrograph determines the depth of the atmosphere above the clouds by measuring the intensity of solar radiation reflected from the cloud tops. Measurements are made in the 7621Å oxygen "A" spectral band.

e. special studies have provided a method for using satellite cloud photographs to determine the location of the jet stream. Knowledge of the location of this phenomenon is especially important to aircraft operations because of the close association between clear air turbulence and the jet stream winds.

f. Public Law 480 counterpart funds are being used to continue support to a research project at the Hebrew University of Jerusalem, Israel. This project is providing interpretation of data obtained over the Middle East by meteorological satellites.

Other Progress in 1965

The first TIROS Operational Satellite (TOS) System spacecraft to be launched early in 1966 will be identical with TIROS IX. This satellite will be followed by a satellite equipped with Automatic Picture Transmission (APT) system cameras. These cameras, already tested on TIROS VIII and NIMBUS I, will transmit local area cloud pictures directly to ground stations within telemetry range of the satellite. The necessary receiving equipment, although relatively simple, was still sufficiently costly that only 11 foreign countries could participate in the APT experiments of TIROS VIII and NIMBUS I. Since then engineering descriptions of less expensive APT ground stations of various configurations and reliabilities have been developed and distributed to member nations of the World Meteorological Organization. As a result some 30 nations will be equipped to receive transmissions from the first APT satellite of the TOS system. A number of other nations have expressed interest, and are expected to join this phase of the World Weather Watch shortly after the TOS system is established.

In connection with the APT program, NESC conducted a training session for representatives of other countries on APT tracking procedures and picture interpretation.

The direct communications link established in October, 1964, to facilitate exchange of meteorological satellite data between the World Weather Centers in Washington and Moscow continued in operation throughout 1965. Although no satellite data have yet been exchanged, the transmission of conventional weather data has resulted in an average saving of one and one-half hours in the twice-daily receipt of conventional data for operational numerical weather prediction. Because of the Soviet announcement that data from USSR meteorological satellites would be forthcoming by year's end, extension of the basic agreement for maintenance of this data link was agreed upon in October, 1965, at a meeting of the United Nations Committee on the Peaceful Uses of Outer Space.

Ionospheric Satellites

EXPLORER XX, the fixed-frequency topside ionospheric sounder launched by NASA in 1964, is now yielding major scientific results. The Institute of Telecommunication Sciences and Aeronomy (of ESSA) has developed new information on the existence of thin sheets of ionization irregularities extending from about 200 km up to thousands of kilometers over certain parts of the globe. The experiments have also provided new insights into the propagation of radio waves in the outer ionosphere in ducts along the earth's magnetic field lines. The sounding experiment is also contributing to understanding the basic physics of plasmas in the collisionless, wall-less laboratory of the ionized upper atmosphere. Plasmas previously had been studies largely in the laboratory. The structure of the plasma resonances observed is unexpectedly complicated and calls for extension of existing theory. These results are some of the bonuses from the basic experiment of satellite global mapping of the ionosphere and its fine scale irregularities.

ITSA scientists participated in planning the ionospheric beacon satellite, ultimately launched as EXPLORER XXII by NASA in 1964. Subsequently they conducted research on the structure and irregularities of the ionosphere by specialized ground observations of the radio transmissions from the satellite. These studies, with others, are contributing to plans for a contemplated operational ionospheric mapping satellite.

Satellite Geodesy

Earth Geodesy--Extensive theoretical studies were performed in the field of geometric satellite triangulation as part of the continuing effort to improve and refine data acquisition and reduction methods. The goal is to obtain worldwide geodetic reference data with accuracies approaching one part in a million.

The effort in satellite triangulation has concentrated on improving the connections between, and the internal consistency of, geodetic control throughout North America, north of Mexico. Two recent cooperative agreements, one between the Governments of the United States and Canada and the other between the Departments of Commerce and Defense, made possible an intensified program to complete the geodetic network in Canada and Alaska, including the Aleutian Islands. The agreements enabled the Coast and Geodetic Survey to activate eight camera systems and to expand measuring and processing capabilities.

Additionally, observations were completed along the arc of satellite triangulation extending from Antigua, through stations at Bermuda and within the United States, to stations in northern Canada.

The launch of PAGEOS in June, 1966, will begin the worldwide geodetic satellite program which has the objective of establishing a global network of 69 spherical triangles, obtained from observations taken at 38 ground stations.

Lunar Geodesy (Selenodesy)--A systems concept study was prepared for the APOLLO program, and a proposed experiment to be conducted in lunar orbit was approved. The objectives of the experiment are: (1) to establish a selenocentric (moon-centered) coordinate system related unambiguously to the equator system of coordinates; (2) to derive a reference figure for the moon with respect to a point which is representative of the moon's center of mass; (3) to create a three-dimensional selenodetic control system over the entire surface of the moon--in terms of latitude, longitude, and height above the derived reference figure--in support of contemplated data collection systems for the compilation of topographic maps at various scales; (4) to provide a detailed description of the gravitational field of the moon; and (5) to develop a data acquisition system and data reduction methods applicable to similar experiments in earth orbit and to the scientific exploration of the planets. Results of the experiment will contribute to the solution of geophysical and geological problems associated with the exploration of the moon and those concerned with the origin of the earth-moon system.

Navigational Satellites

An evaluation of the Navy Satellite Navigation System for possible use in oceanographic survey work was made by the Coast and Geodetic Survey. The System was evaluated on tracklines connecting Oakland, Calif., with positions in Alaska and Hawaii. Comparisons were made with dockside or at-anchor fixes, using precise visual control at each location. Satellite navigational fixes were also collated with visual, radar, Loran C, Loran A, and astronomic fixes while underway. Two orbiting satellites were used during the entire evaluation period.

It was concluded that the Navy Satellite Navigation System is the best available operational system for navigational control of oceanographic survey work. Active application of the system to future oceanic surveys will continue. The limited number of usable satellites in orbit makes possible only a small number of fixes in any 24-hour period. Additional satellites will be needed to provide more frequent positions for the oceanographic survey program.

Geomagnetic Activities

A study of the worldwide secular change of the magnetic elements over recent decades, employing available observatory and repeat data, was completed by the Coast and Geodetic Survey. A machine-reduction program, using the resultant secular-change patterns, obtained values for 1965 at all available field observation points (more than 200,000 in all). A new technique was used to develop a mathematical model of this geomagnetic field from the reduced data. This technique involves an analytic presmoothing by overlapping quadrangles, a provisional spherical harmonic analysis for filling gaps and weak areas, and a final analysis with a degree of fineness not attempted previously. The model is adapted for extrapolation upward to form estimates of the field at various altitudes--up to the limits of the magnetosphere.

Space Environment Investigations

Rocket and satellite studies as well as space research by ground-based techniques and supporting laboratory investigations form part of the program of ITSA, which is located at Boulder, Colo., (formerly the Central Radio Propagation Laboratory of the National Bureau of Standards). Supporting research undertaken by ITSA staff includes theoretical, observational, and laboratory studies of the nature of the ionosphere, the magnetosphere, interplanetary space, and the sun.

ITSA scientists have participated in two rocket launchings to probe the variation of electron density of the lower ionosphere. Scientific results continue to come from the large Jicamarca (Peru) ionospheric radar, which has a range of 10,000 km and more. Laboratory measurements at Boulder have provided positive-ion coefficients for reactions of importance in the ionosphere, many for the first time. This is enabling the theory of the production and maintenance of the ionosphere to be put on a much sounder basis than heretofore. Extensive studies are being conducted on "polar cap absorption events" attributed to bombardment of the earth's atmosphere by energetic protons from the sun. The ground-based radio techniques (riometer and ionospheric forward scatter) in networks in both hemispheres and some at magnetically conjugate points, provide for a measure of the energy spectrum of incoming particles, in effect using the earth as a giant mass spectrometer. A new phenomenon has been identified, attributed to the precipitation into the lower ionosphere of relativistic electrons from the outer zone of the trapped radiation belts. These and other studies are throwing light on the outer boundary of the earth's magnetosphere and the changes during disturbances.

Increased emphasis has been placed on readying a space-environment forecasting service which will be of increasing practical importance to man's activities in space. These studies involve disturbances in the upper atmosphere, in space, and on the sun. Systematic forecasts of some parameters are now being made.

The radio propagation and telecommunications activities of ITSA include several programs specifically directed towards aeronautic and space applications. Studies for the communications satellite program have concerned the practicability from a propagation standpoint of sharing frequencies between satellite and earth-bound communication services. Other studies have been made of the degree and nature of interference to space communications arising from thunderstorm cells, aircraft, or the unwanted signals from other services using the same frequencies. ITSA scientists have also investigated for NASA the limitations on the accuracy of spacecraft and aircraft radio tracking systems imposed by the spatial and time variability of the refractive index of the atmosphere. The results will be useful in optimizing the design of such tracking systems. Special propagation studies and calculations have been made to assist the development of the U.S. position on plans for sharing the use of radio frequencies for aircraft communications. Typical flight paths and reporting locations have been selected in all the major world air route areas, and computations have been made of the theoretical reliability of each frequency band at various times, seasons, and solar activity levels.

Support for NASA Space Operations

Telecommunications and Aeronomy Support--In the role of consultants to NASA, ITSA scientists have helped plan experiments to be carried out on manned satellites including the briefing and debriefing of the astronauts. The experiments concern the airglow layers in the high atmosphere, the twilight bands, and the zodiacal light due to sunlight scattered by interplanetary dust.

Services to the space program include special advance predictions of radio frequencies for communication among the ground control stations of the GEMINI program. These are supplemented by special and up-to-the-minute forecasts of propagation conditions and disturbances during the course of each mission. Experimental solar flare forecasts are also provided. Ionospheric sounding observatories at several rocket and satellite launching sites contribute both to operations and research. Under an international arrangement with COSPAR, the radio and geophysical forecast center operated by ITSA assigns the international designations to all satellites and space probes launched, and serves as the Western Hemisphere center for notifying the scientific community of launchings and relevant orbital information.

Seismic Support

The seismic energy induced by three SATURN (SA-7, SA-8, and SA-10) launches was monitored with seismic instruments to obtain ground vibration measurements. Based on these measurements, the C&GS derived prediction equations to permit extrapolation to the anticipated vibration levels that would be generated by more advanced missile-launch systems. The static firing of 1.5 million-pound thrust F-1 rocket engine was also monitored to provide additional data for ground-motion prediction studies pertinent to missile launches.

Using seismic techniques, rocket propellant-TNT equivalence studies were conducted during the intentional destruction of a 91,670-pound liquid propellant SATURN IV engine and a 28,000-pound solid propellant MINUTEMAN missile.

Meteorological Support

The Weather Bureau continued to provide meteorological services to the National Aeronautics and Space Administration in support of the manned spaceflight program. Noteworthy among the types of support provided were the operational forecasting services furnished for the several GEMINI missions. In the GEMINI 5 mission where adverse weather conditions were expected in the planned landing area as a result of Hurricane Betsy, the flight was terminated one revolution earlier than scheduled, in an area where excellent recovery conditions existed. Other significant support consisted of developmental and environmental studies, such as toxic fuel dispersion, wave slope characteristics in the open oceans, and climatological conditions near the ocean surface. Such support was utilized by the NASA Manned Spacecraft Center in the design, test, and evaluation of aerospace systems and components in the GEMINI and APOLLO programs and in facilities planning and maintenance at the NASA Kennedy Space Center.

The Bureau also conducted an extensive program of meteorological observations and forecasting services in direct operational support of NASA and Department of Defense range activities.

NATIONAL BUREAU OF STANDARDS

Much of the National Bureau of Standards measurement and standards research supports the capability of American industry to meet the needs of the Nation's space and aeronautics programs. For example, during the year, the Bureau: (1) put into operation new facilities for calibrating the devices used to measure rocket thrust (the more accurate measurements possible with the new facilities can reduce the number of test firings needed in the development of a rocket); (2) developed a new method for producing "slush hydrogen," a material which looks promising as a rocket fuel; (3) announced an industry-government cooperative research program on the techniques for handling liquefied gases such as those used in rocket fuel systems; and (4) began preparation of new spectrochemical standard materials which will aid in the detection of metal in the oil of conventional aircraft, and thus detect incipient failure of metal parts.

Introduction

The programs of the National Bureau of Standards in measurement, materials research, and engineering standards, are important in a variety of ways to the national effort in space and aeronautics. The host of experimental measurements made by space probes depend for meaning and interpretation on the standards of measurement maintained by NBS. These measurement standards, along with engineering standards developed by the Bureau, enable the Government to specify hardware and systems, and enable industry to bid intelligently on contracts and sub-contracts. The Bureau's materials research contributes to the development of materials for demanding space applications.

Basic Measurements and Standards

The provision of measurement services to the space program was extended and improved through new facilities and services. Three new deadweight machines with 112,000, 300,000, and 1,000,000 pounds-of-force capability were placed in operation at the NBS installation in Gaithersburg, Md. These machines, providing NBS nine times its previous force capability, are used to calibrate devices which measure rocket and jet engine thrusts. The greater the force provided by such machines, the more accurate the calibrations possible. Since more accurate measurement reduces the number of costly test firings required, these machines promise economies for the Government in engine development activities.

The Bureau extended its vacuum calibration service over a wider vacuum range. Initially, this extended service covers 1 to 1000 millitorr (1/760,000 to 1/760 atmospheric pressure). This pressure range is important in the development of aerospace equipment, since it corresponds to an altitude range of approximately 150,000 to 300,000 feet.

Another space-related measurement development is the radiometric standard for calibrating radiation detectors used for ultra-violet measurements in space.

For NASA's Orbiting Astronomical Observatory satellite, NBS developed a star simulator. Light from this simulator has the illumination and color temperature of a visual second-magnitude star and will be used to calibrate star-tracking equipment.

The specific needs for measurement techniques and data for the investigation of space, the planets, and the stars are reflected in NBS work. The space program has provided the unusual opportunity to observe the light given off by stars from orbiting satellites, free from the interference of the atmosphere. Interpretation of data requires understanding of the atomic and molecular reactions which produce the light. Among NBS accomplishments in investigating these processes are:

a. determination of more accurate atomic transition probabilities--neon, argon, carbon, nitrogen, and nickel. Resulting experimental figures in many cases replaced questionable theoretical values or conflicting experimental data.

b. better data on the contributions of negative ions to the light from both stars and planetary atmospheres. These data will be of particular value to plasma physics and atmospheric physics.

Other projects in atomic physics contributed to specific areas of space technology:

a. data on light given off by compounds of aluminum, beryllium, lithium, and other light elements were developed. These data will aid in the investigation of rocket fuel combustion and the hot gases surrounding a re-entering space vehicle.

b. calculating techniques were developed to better understand the penetration of high-energy electrons through matter. These techniques will aid in solving spacecraft shielding problems and will facilitate interpreting radiation data obtained in satellites.

c. data developed on the light-absorbing and reflecting properties of plant and animal materials will be invaluable to future searches for extra-terrestrial life, particularly on Mars.

In another project, NBS developed a new lighting system for use on helicopter rotors. These lights will increase safety of helicopter operations in both civilian and military operations. A significant feature from the military standpoint is that the lights can be set during installation so that they are visible only in selected directions.

Materials Research

The use of liquefied gases as fuel in rockets has been advanced in many ways by NBS research. During the year, the Bureau continued its study of the characteristics of a potential advanced rocket fuel--consisting of a mixture of solid and liquid hydrogen. This mixture, called slush hydrogen, would have two advantages over presently used liquid hydrogen--it requires less storage space and has a considerably longer storage time. NBS developed a new method of producing slush hydrogen which could be extended to quantity production.

Also, the Bureau announced a joint program of industry-government research which should contribute to improvement of systems handling low-temperature liquids. Under the NBS Research Associate program, a specialist was obtained from industry to study fundamental properties of low-temperature fluids, and how they act while flowing and as they are subjected to heat.

A number of studies were done on the effects of the outer space environment on materials which might be used in building space vehicles and components.

Studies were made of the effects of radiation on the mechanical properties of metals and plastics. The knowledge gained will be invaluable in selecting materials for use in outer space, and in predicting its performance. Another study showed the changes to be expected in the behavior of optical glass subjected to intense radiation. Telescopes, tracking systems, and other optical devices for use in outer space can be better and more reliably designed when these factors are taken into account.

Radiation is not the only extreme factor in space vehicle and aircraft operation. One NBS study developed information on the high-temperature stability of the refractory metals. These data play an important role in the design of metal structures which must survive extremely high temperatures. Chemical environments are also often demanding. A study was initiated on the effects of stress-corrosion on a titanium alloy being considered for the wings of the 2,000 mph aircraft.

Corrosion is a problem on the ground, too. At NASA's request, NBS began providing technical assistance in protecting the gantries and other equipment at Cape Kennedy from corrosion in the marine atmosphere.

NBS standard materials are used in many space and aeronautical applications. During the year, the Bureau began preparation of three new beryllium-copper alloys. Industry stated that analytical standards for these alloys are required for both production control and consumer acceptance. Perhaps $50 million worth of these alloys are used each year, and they are particularly important in electrical and electronics space hardware.

The Bureau also agreed to prepare metal-in-oil standard reference materials for calibration of spectrochemical equipment used to analyze lubricating oils in military aircraft. Such analysis prevents failures and monitors overhaul programs for all types of equipment. The Air Force alone claims 31 aircraft saved during the first year at MacDill Air Force Base through this means.

Engineering Measurements and Standards

In order to evaluate and utilize most efficiently the many complex devices used in space and aeronautic applications, the engineer must have reliable ways of measuring their behavior. An example of the NBS contribution to this work is the establishment of a program on solid state nuclear radiation detectors, such as are used in satellites. The program provides the measurement basis for the improvement of reliability and operational lifetime of these devices, and guidance to other agencies in selection and use. At the same time, NBS operates a small-scale fabrication facility to supply special-purpose detectors not commercially available.

OFFICE OF THE UNDER SECRETARY FOR TRANSPORTATION

Development of a Supersonic Transport

The parametric cost-benefit analysis completed in mid-1965, by the Department of Commerce at the direction of the President, was directed at the impact of new aircraft types in the supersonic and subsonic regimes on the aircraft manufacturing industry, on U.S. exports, on U.S. airlines, and on the quality and cost of air transportation.

The Department, in conducting this study, had assistance and cooperation from the Civil Aeronautics Board, Department of Defense, Federal Aviation Agency, National Aeronautics and Space Administration, Department of Treasury, the Air Transport Association, Airport Operators Council, the aircraft and engine manufacturing industries and the airline industry. The report upon completion was submitted to the President and to the President's Advisory Committee on Supersonic Transport.

It is expected that the Department, due to its broad policy responsibilities, will maintain a continued interest and activity in the development program of the supersonic transport.

SPACE SCIENCE BOARD

CHAPTER IX

INTRODUCTION

The National Academy of Sciences, a private organization of scientists and engineers that serves as an official adviser to the Federal Government, is called upon to advise the government on scientific aspects of the space program. These advisory services are carried out on behalf of the Academy by its Space Science Board. In addition, the Board furthers space research generally by promoting the discussion of advances and opportunities in the field. Internationally, the Board, on behalf of the Academy, represents the United States scientific community on the Committee on Space Research (COSPAR) of the International Council of Scientific Unions (ICSU), and has collaborated closely with that committee. The committee serves to encourage and guide international cooperation in space research, to facilitate the exchange of information, and to elicit the interest and participation of scientists throughout the world.

Committees

To accomplish its work the Board with an Executive Committee and a small number of standing committees holds regular meetings. The Committees are: Surfaces and Interiors of the Moon and Planets, Life Sciences, Geodetic Uses of Navigational Satellites, High Altitude Rocket and Balloon Research, Potential Contamination and Interference from Space Experiments, and several ad hoc groups. The Board maintains continuous and close liaison with the scientific subcommittees of the NASA Space Sciences Steering Committee. In its relations with the international scientific community, the Board works through its Committee on International Relations, which maintains liaison with NASA, the Department of State, the FCC, the DOD and other interested government departments and agencies.

THE NATIONAL PROGRAM

Congressional Testimony

In response to an invitation from the Chairman of the Senate Committee on Aeronautical and Space Sciences to the President of the Academy, the Chairman of the Space Science Board and two of its members presented testimony before the Senate Committee in August 1965 about the post-APOLLO goals of the immediate future (before 1975) and for the period after 1975. The MARINER IV mission was recognized as a major contribution to planetary exploration, and the exploration of Mars was reaffirmed as one of this country's primary goals in space.

Woods Hole Summer Study of Space Research

In the Fall of 1964 discussions between members of the Space Science Board and the National Aeronautics and Space Administration suggested that it was timely for the Board to undertake a study of certain principal areas of space research. Plans were made accordingly, and specialists from several scientific disciplines were convened in a Summer Study at Woods Hole during June and July, 1965. Space Research: Directions for the Future is the report of that study (in press). For convenience the report is presented in three parts. Part I is devoted to planetary and lunar exploration. Part II takes up four branches of astronomy and some special topics in physics and geophysics. Part III discusses several subjects--in particular, rocket and satellite research, university programs, medicine and physiology, and biology.

In contrast to the general review of space research in the 1962 study, the objectives in 1965 were limited: first, to develop a program of planetary exploration and to recommend priority within it; second, to determine the needs of astronomy in space; and, third, to consider the role of man in space research. All of these tasks were to be regarded in the light of the post-APOLLO period, extending through about 1985.

The study itself divided naturally into two two-week sessions: (a) June 20-July 3: Working Groups on Optical Astronomy, Solar Astronomy, Radio and Radar Astronomy, X-Ray and Gamma-Ray Astronomy, Physical Sciences, Medicine and Physiology, and Biology and (b) July 5-July 16: Working Group on Planetary and Lunar Exploration. Related topics were covered in shorter sessions during the course of the study. On July 5 for the first session and on July 16 for the second session, the study convened in reporting sessions to discuss findings and recommendations.

Space Research: Directions for the Future contains detailed recommendations in each of the selected subjects and looks forward in the post-APOLLO period to systematic investigation of the planets; to large orbital astronomical observatories; to the extension of the contributions of manned flight to space research; to a balanced program concerned with near space and the interplanetary medium using ground-based observations, observations from balloons, sounding rockets, satellites and space probes in complementary fashion.

Life Sciences

During the past year, the Life Sciences Committee of the Board examined the following subjects:

Radiation and Manned Spaceflight

a. radiation-protection guides for manned space flight operations;

b. biological responses of man to radiation that are of most importance in affecting the success or failure of a given space mission; and

c. dose-response relationships for radiation effects of most importance in missions of less than two years' duration.

A report of this study is in the final stages of preparation.

Space Nutrition

The Panel on Space Nutrition began a review of current research programs in flight nutrition and waste handling for space missions of long duration.

Medical Experiments

An ad hoc working group has reviewed the bio-medical experiments planned for the GEMINI and APOLLO space flights.

Gaseous Environment of Manned Spacecraft

The gaseous environment of the U.S. manned spacecraft has been 100 percent oxygen at five psi; approximately one-third the normal Earth pressure. Despite the success of MERCURY and GEMINI manned flights with a 100 percent oxygen cabin atmosphere, the physiological effects of this kind of atmosphere for prolonged flight are essentially unknown and the danger of explosion and fire remains. A working group of the Life Sciences Committee studied this problem in 1965 and reported its recommendations to NASA for additional simulated flight experiments with different gases and pressures, more extensive physiological studies and thorough investigation of fire hazards.

Treatment of Extraterrestrial Samples

In January 1965 the Board, at the request of the NASA, appointed a committee to study the problem of handling lunar samples returned to Earth. The committee recommended the designation of a special facility to receive returned samples and hold them for quarantine for a period of time yet to be determined. Radioactivity measurements and a general inspection by Public Health authorities for potentially harmful biological properties should be made as soon as practicable after samples are returned to Earth. Once a sample has been released from quarantine, other measurements and analyses can be performed at any suitable laboratory. While this study had primary reference to handling samples of the Moon, the recommendations would also apply generally to samples brought back by any spacecraft.

Exobiology

The 1964 Report to Congress noted progress in a Board-sponsored Study of Exobiology. The study was completed in 1964, and a Summary Report (Biology and the Exploration of Mars) was published in April 1965. In October 1965, the Exobiology Study Group was reconvened to consider the results of studies of photographs of Mars and of other scientific data obtained from the MARINER IV mission, and other recent data on Mars. The full report with a postscript taking into account the MARINER IV data, will be published in early 1966, with a companion volume containing a bibliography of approximately 2000 entries and an anthology of 33 papers. The Summary Report notes that scientists consider that the likelihood of finding living matter is greater on Mars than on any of the other planets in the solar system. The report advocates the exploration of Mars as a systematic scientific study to learn whether life has ever existed there or not, and to investigate the Marine environment in order to obtain a better understanding of planetary development and of the circumstances that may have permitted or prevented the development of life. The MARINER IV mission confirmed the long-predicted craters on the Martian surface, and allowed refinement of estimates of the physical properties of the planet and its environment. While confirming the contemporary assessment of the Martian surface environment as extremely harsh, the results indicate that the surface features now seen may be of quite recent origin in terms of geological time. The existence of milder conditions early in the planet's history (at a time corresponding to that during which life arose on the Earth) is therefore not excluded. The changes that the present evidence indicates must have occurred on Mars encourage the view that conditions permitting the survival of evidence of biological activity may exist in particular localities.

The NASA asked the Space Science Board for advice on the potential for planetary contamination represented by microorganisms contained inside spacecraft components, the contamination that might result from landings hard enough to fracture such components, and the means and standards for component sterilization. The Life Sciences Committee held a conference on the subject in July 1964, and their report, dated March 1, 1965, recognizes that terminal sterilization of the entire spacecraft by dry heat is the preferred method. The report recommends that, where dry heat is not possible, new methods and techniques should be developed to achieve the desired levels of sterility.

An International Conference on Contamination and Sterilization was recommended by COSPAR at its 1964 and 1965 meetings. This conference is now tentatively scheduled for 1966. (A national conference designed to acquaint industry with the problems of sterilization was held by NASA in November 1965.)

Contamination of Earth with extraterrestrial organisms (back contamination) returned with or on spacecraft poses problems of unknown scope but of potentially catastrophic significance. The handling of deliberately acquired specimens of lunar origin have already been discussed. With additional considerations, the same plan applies to deliberately acquired specimens of the planets. However, astronauts and returned spacecraft are potential sources of contamination that must be dealt with in a different manner.

NASA and the Sustaining University Program

The universities contribute substantially to the quality of the space research program, both by participation and as a source of scientifically trained people. An *ad hoc* committee of the Board was convened to review the support of the universities that the National Aeronautics and Space Administration provides and reported its findings on April 21, 1965.

The committee commended NASA for its initiative and constructive efforts toward developing a healthy relationship with academic institutions of higher learning. The Sustaining University Program was endorsed in all its elements and recommendations for a modest increase in level of funding were offered. These recommendations were also adopted by the Working Group on NASA-University Relationships of the Woods Hole Summer Study and its findings incorporated in the report of that Study.

Selection of Scientist-Astronauts

In 1965, the Space Science Board reported to the NASA the results of the work of an *ad hoc* committee on the selection of scientist-astronauts. The committee's work was conducted by two groups: one group considered applicants with physical sciences backgrounds, and the other considered applicants with training in the biological sciences. The NASA selected six of the applicants as scientist-astronauts from among those recommended by the Board.

INTERNATIONAL ACTIVITIES

Eighth Meeting of COSPAR

The Board provided organizational direction for participation of U.S. scientists in the Eighth Plenary Meeting of the Committee on Space Research (COSPAR) of the International Council of Scientific Unions, held jointly with the Sixth International Space Science Symposium, at Mar del Plata, Argentina, May 11-21, 1965. Scientific presentations were made by scientists from several countries, notably the U.S. and the U.S.S.R.; there were 310 attendees in all. Separate sessions were held on Tracking, Telemetry, and Dynamics; the Program of the International Years of the Quiet Sun (IQSY); Space Data Exchange; the International Reference Atmosphere; and Space Biology. The themes of the meeting were: to foster international exchange of science; to encourage additional nations to participate in international space activities; and, consistent with continued exploration of space, to take measures to insure that early missions do not contaminate planetary environments with terrestrial organisms. As is customary, the scientific papers presented at the meeting are being collected and published.

World Data Centers

The World Data Centers, established under the auspices of the International Council of Scientific Unions, collect data from many geophysical sources, especially ionospheric physics, solar activity, aurora, airglow, geomagnetism, and meteorology, and from a great variety of experiments on board rockets, satellites, and spacecraft. There are three World Data Centers: World Data Center A, in the United States; World Data Center B, in the U.S.S.R. and Czechoslovakia; and World Data Center C, in Western Europe and Japan. Each Data Center is divided into a number of Subcenters representing the major disciplines of geophysics and space research. The Rocket and Satellite Subcenter of the World Data Center continues to function under the aegis of the Space Science Board. The Subcenter collects and exchanges results of research conducted with spacecraft and sounding rockets. A bibliography of reports and papers published in 1964 was submitted to COSPAR in early 1965, as is customary.

SMITHSONIAN ASTROPHYSICAL OBSERVATORY

CHAPTER X

INTRODUCTION

This year, the Smithsonian Institution Astrophysical Observatory's 75th anniversary was a time for researching its origins as well as for evaluating its achievements. The Observatory was established in 1890 as a center for studies of solar radiation and its effects on the earth. During the next 65 years it made significant estimates of the solar constant from data derived from a network of observing stations, and carried out other astrophysical projects.

During this last decade the Observatory has played an increasingly significant role in the space program of the United States. Today, data are obtained from a world-wide network of astrophysical observing stations. An unmanned network of 16 camera stations in the Midwestern United States is used for photographing bright meteors; a system of radar and optical tracking stations on the Virginia coast observes simulated meteors; a radar system in Illinois detects ionized trails from meteors; and space science laboratory work is conducted.

OPTICAL SATELLITE TRACKING PROGRAM

The Observatory operates a network of 12 Baker-Nunn camera stations around the world for the precise optical tracking of satellites. One hundred Moonwatch teams and affiliates of volunteers make visual sightings of satellites; the observation and possible recovery of re-entering satellites is also one of their important objectives.

The re-entry and disintegration of the Gemini 5 second-stage rocket body was photographed by the Smithsonian station in South Africa. These photographs, made with a special Baker-Nunn satellite tracking camera, are thought to be among the first made of a re-entering satellite. They indicate that upon hitting the denser air of the earth's atmosphere after the 50th revolution in space the body broke into at least 47 individual pieces.

The Observatory also supplied tracking support for the three PEGASUS meteoroid-penetration satellites, and for the GEOS (EXPLORER) satellite.

During the year a cooperative program was initiated with the Air Force to use its Baker-Nunn cameras, particularly at Oslo, Norway and at Cold Lake, Canada to gain more precise geodetic information. The Observatory has also carried out cooperative observing programs with the British government operating instruments at Malvern, England, and with the Coast and Geodetic Survey cameras operating in northern North America.

Satellite tracking data continue to yield significant advances in our knowledge about the upper atmosphere. Densities have been computed for the neutral atmosphere starting with a fixed set of boundary conditions at 120 kilometers and following empirical temperature profiles defined by exponential functions of height. These models have been adopted by the U. S. Committee on the Extension of the Standard Atmosphere for inclusion in the U. S. Supplemental Atmospheres, together with the appended formulas that give the variations of temperature with solar, geomagnetic, and geographic parameters. A seasonal effect has been found to exist at middle and high latitudes at all heights up to 600 kilometers. At any given height above 200 kilometers, the atmosphere has a maximum density in winter and a minimum in summer.

Geodetic studies from observations of satellites, both by the intervisible (geometric) and by the orbital (dynamic) method, continue to make possible more accurate determinations of the coordinates of the astrophysical observing stations. A program to combine the results of these two methods shows that in the determinations of the coordinates, the results are in good agreement.

From precisely reduced observations of nine satellites of different inclinations, new values for the coefficients of the zonal harmonics of the geopotential have been derived. And from 26,000 observations of 11 satellites of differing inclinations, a new set of tesseral harmonics has been determined.

Analysis of zonal harmonics has suggested that the load of the last continental ice sheets, which persisted some 50,000 years near the end of the Pleistocene period, may have deformed the earth, flattening it near the poles and causing a bulge near the equator. Since the ice sheets retreated only some 11,000 to 15,000 years ago, there has been too little time for the earth to completely recover from the effects of this deformation, and the residual of this deformation therefore remains in the earth's ellipticity.

Simultaneous photoelectric and photographic observations of an artificial satellite were made by combining a laser system with a satellite-tracking camera. The laser-camera experiment demonstrates the feasibility of using the laser system to increase the utility of Baker-Nunn photographic tracking. The simultaneous laser observation aids the calculation of precise ranging, or line-of-sight distance measurements from the satellite to the ground tracking unit.

METEORITIC STUDIES

Ground-based photographic and radar instruments provide data on the meteor process as they record the trails of fragments of matter plunging through the earth's atmosphere from space.

During the year, the Prairie Network photographed 99 bright meteors from more than one station, with resultant films of adequate quality for reduction to orbits. An additional objective of the Network is to locate and study in the laboratory those bodies surviving to the earth. Freshly fallen meteorites provide valuable data on the radiation exposure to which they were subjected, information that can be of value to scientists planning space projects.

In Illinois, a radar installation jointly operated with the Harvard College Observatory has yielded observations of some 10,000 ionized meteor trails. When reduced and analyzed, these observations will provide a substantial body of data for research into the astronomy and physics of meteor particles as well as for the study of other upper-atmosphere phenomena.

To complement the study of natural meteors, a radar system has been set up near Wallops Island, Virginia, to detect the re-entry of manmade meteors. This work is correlated with that of a network of three cameras for photographing the artificial meteors. During this year the first simultaneous radar and optical photographs were taken of an artificial meteor.

The Observatory continues to derive fruitful results from its analysis of meteorites and micrometeorites. Study of particles collected from melted snow within the Greenland ice sheet revealed the presence of cobalt-60, the characteristics of which have been tentatively ascribed to iron-60 produced by cosmic rays. Mass-spectrometer studies of rare gases extracted from sea sediments and from the Greenland materials confirmed the anomalous argon isotope ratios previously reported.

Investigations of meteoritic minerals by the method using the tracks left by fission fragments indicate that uranium is not dispersed in meteorites, as was previously believed, but rather is concentrated in certain minor accessory materials, notably whitlockite and zircon.

The electron-beam microanalyzer has been used to establish the probability that nearly 300 dust particles collected from Arctic ice deposits are primarily extra-terrestrial in origin.

COMETARY STUDIES

The Astrophysical Observing Stations gather data for the study of comets. Photometric observations of four comets, including Ikeya-Seki and Everhart, have been obtained. These films are analyzed for correlations with solar phenomena and for indications of the physical behavior of comets.

All of the Baker-Nunn cameras have been equipped with a plastic defocusing device; measurements of the image density of photographs made through these optics reveal the total brightness of a comet. These photometric observations have been analyzed for correlations with solar phenomena and for indications of the physical behavior of comets.

It has now been determined that streams of solar particles reaching a comet play a significant role in its activity; the apparent motion of bright streamers in comet tails has been under study, using Baker-Nunn photographs.

The discovery of the Comet Ikeya-Seki on September 18, 1965 was immediately confirmed by the Baker-Nunn camera of the Observatory. In the weeks that followed, the comet -- the largest, longest, and brightest in many decades -- was observed and photographed every 15 minutes it was visible to individual stations in the Baker-Nunn system. The photographic data -- besides providing immediate information for thousands of positional astronomers and interested amateurs around the world -- would later be used in the Observatory's continuing studies of cometary physics, including comet photometry and studies of the relationship between solar activity and tail motion. Sequences of photos may also be used to produce a motion picture documenting the growth and movement of the comet's tail.

The Astrophysical Observing Stations provide the only known global system of identical optical instruments capable of photographing a comet continuously throughout its orbital lifetime.

From time to time a comet nucleus is observed to break into several pieces. Sometimes two or more comets are thus formed which subsequently follow nearly identical orbits. Other times the original comet simply vanishes, leaving only the suspicion that its nucleus fragmented. The Director conducted a study of twelve such split comets. The fact that these appear to be "new" rather than periodic comets leads to the suggestion that early in its life, each of these fragmented comets was a large dirty snowball containing a source of heat in radioactive atoms. Planetary encounters eject the comet far out of the solar system and into interstellar space where sublimation of the more volatile materials depletes the core over a long-time interval. Diffusing outward through the nucleus, the gases recrystallize in the extreme cold near its surface to form an external shell that is brittle and a structurally weakened core. During its long stay in interstellar space, the comet is affected by virtually no external physical forces. Thus on its first close approach to the sun, exposure to strong external radiation may result in the formation of heat shock that causes the comet to split. Substantiation of this theory came when Comet Ikeya-Seki after its passage close to the sun split into two and possibly three fragments.

OTHER SPACE STUDIES

Using improved instruments and techniques, the astrophysical observing stations are measuring the earth's albedo -- the amount of sunlight reflected from the earth to the dark portion of the moon and back to earth again. The faint illumination of this portion of the moon can indicate how reflective the earth is.

Other studies deal with the astrophysical implications of autoionization in atomic spectra. A considerable number of previously unobserved and unidentified features have been found in the solar spectrum. In its oval path, Mercury swings close to the sun every 88 days. On one close approach, the planet "faces" the sun, and on the next it presents its other side to the sun. An analysis has shown that to accomplish this maneuver, the planet rotates about its axis in exactly two-thirds of the time required to orbit the sun. Hence Mercury has precisely one and one-half days per year. The new rotational period of Mercury at exactly 58.65 days was recognized as an astronomical "locking-in process" never before observed.

FEDERAL AVIATION AGENCY

CHAPTER XI

INTRODUCTION

Nearly all major measures of U. S. air activity in 1965 topped previous 12-month totals. Significant advances continued to be made in aeronautical technology, and commercial aviation recorded an exceptional year of economic growth.

The Federal Aviation Agency's activities during the year reflected these forces for growth and technological change in air transportation; they also mirrored substantial achievement towards insuring the continued progress of U. S. aviation.

The Agency worked to advance the Nation's aviation through its major missions of assuring the safe and efficient use of the national airspace for commerce and defense, fostering civil aeronautics and air commerce at home and abroad, and promoting air safety.

ADVANCES IN AIRSPACE USE AND CONTROL

National Airspace System

The present and projected growth of flight activity, coupled with the prospect of civil supersonic aircraft, gave special urgency to Agency efforts to evolve a National Airspace System (NAS) responsive to tomorrow's aviation needs. For the air traffic control subsystem of NAS, the Agency plans the use of new computerized equipment to give controllers a constant three-dimensional radar picture of air traffic along the Nation's airways. Greater automation throughout the system is designed to relieve the controller of most routine duties, enabling him to concentrate on the continuous monitoring of air traffic and freeing him for making critical control decisions. Progress was made during the year in the following major programs aiming to bring modern technology to bear on air traffic control problems and to put the tools of automation into the hands of the controller.

ARTS and SPAN

Year-long field tests began in 1965 of computerized equipment which electronically tags aircraft target "blips" on the controller's radarscope with luminous letters and numerals (alphanumerics). The alphanumerics identify the aircraft and indicate its altitude and other selected flight data. Designed for a medium-density air traffic terminal served by a single airport surveillance radar, the advanced radar traffic control system (ARTS) is being tested at the Atlanta airport control tower. A test of stored program alphanumerics (SPAN), the en route application, is underway in the high-altitude sectors of the Indianapolis air route control center, which is served by multiple long-range radars. At year's end FAA announced plans to install the alphanumeric system of semi-automated air traffic control in the congested New York area within two years - a year ahead of the original schedule.

NAS: En Route and Metroplex Stages A

ARTS and SPAN are trial applications of control techniques and procedures using equipment similar to the devices being developed for the more highly automated air traffic control subsystem of the national airspace system. During the year FAA let contracts for major components of the En Route Stage A portion of this highly automated system. Initial installation of an engineering model at the Agency's National Aviation Facilities Experimental Center (NAFEC) is scheduled for mid-1967 and the start of field tests at the Jacksonville air route traffic control center for early 1968.

Much of the En Route Stage A hardware will be used in the NAS Metroplex (Metropolitan complex) Stage A, the first stage of a two-stage effort to develop advanced equipment and control techniques for high-use terminal areas. The "software" requirements--computer programs, procedures, and the like--differ markedly, however, because of the different operational practices in terminal and en route areas. A Metroplex Stage A system description and general specifications for its operation were drafted during the year. Further major steps toward this advanced terminal system are phased to follow counterpart stages of en route development by approximately one year.

In-Service Improvements

Advances toward a more modern airspace system resulted also from improvements to the Nation's present air traffic control and air navigation system. Highlights of the year included:

a. completion of the program started in 1959 to consolidate and reduce the number of air route traffic control centers (ARTCC's) in the contiguous 48 States from 29 to 21.

b. installation of computer updating equipment (CUE) at four additional ARTCC's. At five high-activity centers, controllers are now able to update flight movement data stored in the computer and receive revised information without leaving their operating position.

c. development of trailer-type air navigation aids and radar units that are mobile or readily relocatable to assure reliable and continuous services at reduced costs.

d. use at New York's John F. Kennedy Airport of the first of seven scheduled distance-measuring equipments (DME) to be combined with instrument landing systems (ILS). Providing the pilot of appropriately equipped aircraft with continuous information on his distance to touchdown, the new ILS-DME combination thus contributes to safety and operational efficiency during instrument approaches.

Field tests of FAA's proposed flight service station (FSS) modernization plan were completed in mid-1965. Results indicated that although aeronautical needs can be met at some such stations with less than 24 hours a day operation, extensive consolidation of existing stations is not warranted at this time. The "do-it-yourself" airport information desks are valuable aids in flight planning. Based on the need for this service, criteria for their establishment are being developed.

In carrying out its mandate to establish and operate a common airspace system to serve both civil and military users, FAA continued to work with the Department of Defense in a number of cooperative activities. To avoid costly duplication of personnel and equipment, FAA and DOD share the use of certain facilities when both air traffic control and air defense requirements can be met by such joint use. As 1965 ended there were 39 FAA-military terminal radars and 56 long range radars (LRR's) in the common surveillance system, and 23 more LLR's are programed to serve in this dual capacity.

An FAA-USAF program to modernize or replace outmoded airport surveillance radars progressed on schedule during the year.

In May FAA and USAF reached an agreement covering temporary exchanges of mobile flight facilities, equipment, and services when required to meet special or emergency common-system needs. Another FAA-USAF agreement was to co-locate and ultimately consolidate the NOTAM (Notice to Airmen) facilities and systems of the two agencies. The Air Force-operated USAF-USN Central NOTAM Facility was accordingly co-located at the FAA headquarters building with the National Flight Data Center, the central source for flight information issued by FAA.

Testing of new control concepts for military air traffic continued at FAA's air traffic simulation facilities at NAFEC. Procedures for handling high density helicopter movements in forward battle areas were developed from one of these dynamic simulator studies.

Aeronautical Communications

With faster and growing numbers of aircraft operating along the Nation's airways, safe and efficient airspace use hinges increasingly on rapid and reliable communications. To meet present, and prepare for future, aeronautical communications needs, the Agency during 1965:

a. installed the first units in a radio equipment modernization program. In addition to enhancing air-ground communications, the new transistorized equipments are expected to yield substantial savings in operating and maintenance costs.

b. began operating at Point Barrow, Alaska, its first single-sideband (SSB) facility on the high-frequency channels used for long-distance air-ground communications. Use of the SSB technique effectively doubles the number of available channels and improves signal intelligibility.

c. participated in a joint Government-industry experiment using SYNCOM III which demonstrated the technical feasibility of satellite relay stations for long-range aeronautical communications. FAA is also exploring the possible use of such stations for navigation and data-acquisition functions in the air traffic control system.

d. continued work, in concert with other Government agencies, on a long-range program to define characteristics of an advanced air-ground communications system which could eventually replace pilot-controller voice communications with digital data links between aircraft and ground networks.

e. updated the air traffic control frequency assignment plan to provide for 50- instead of 100-kilocycle spacing, thereby increasing the number of available channels.

f. made further progress in carrying out an earlier FAA-DOD agreement to consolidate worldwide the operational communications services of the two agencies.

g. expanded Automatic Terminal Information Service (ATIS). Using magnetic-tape recordings, these continuous broadcasts of wind, weather, runways in use, and other routine noncontrol information ease pilot-controller workload and reduce radiofrequency congestion. ATIS is now operating at 14 of the Nation's busiest airports and will be extended to another 59.

AIRCRAFT DEVELOPMENT

U. S. Supersonic Transport (SST)

In mid-1965, the SST program entered a stepped-up 18-month design and test phase. Supporting research was carried forward in the areas of sonic boom, SST economics, fuels, and materials. Related studies focused on airworthiness standards, flight and air traffic simulation, man-machine relationships, and the physical environment in which the SST will operate. All of these efforts are pointed toward certificating by 1974, or earlier, a safe, commercially profitable SST and maintaining U.S. world leadership in the field of large transport aircraft.

On December 3, 1964, President Johnson directed the FAA Administrator to extend the contract design efforts of two airframe companies and two engine manufacturers. This Presidential action followed in the wake of a second Government-industry evaluation of the design proposals submitted by the four design contractors. Government evaluation of the design proposals was conducted by a 129-member Supersonic Transport Evaluation Group, comprised of FAA, Air Force, CAB, NASA and Navy personnel. Nine U. S. airlines performed independent evaluations.

In February 1965 a study of sonic-boom effects on typical structures at high overpressures was completed at White Sands Missile Range. Nearly 1,500 sonic-boom overpressures generated by Air Force jets ranged from 2.0 to 20.0 pounds. Overpressure levels and responses throughout 7 of the 16 structures, mostly residential in type, were measured by over 100 channels of instrumentation. Preliminary data on the tests were published in March. A comprehensive report of FAA's study of public reaction to the sonic-boom tests at Oklahoma City in 1964 also became available in the spring of 1965.

A Sonic Boom Committee named by the National Academy of Sciences at the President's request continued to provide guidance to the Government on SST sonic-boom research. The Academy's role addresses itself to definition of research requirements, planning for future studies, and evaluation of findings. Economic analysis of the SST was spearheaded by the Department of Commerce, with contract studies conducted by four research organizations.

As design and research work continued, the President's Advisory Committee on Supersonic Transport proceeded with a detailed analysis of the program. Principal members of this advisory committee are the Secretaries of Defense (chairman), Treasury, and Commerce, and the Administrators of FAA and NASA.

In its review of the program the committee gave prime consideration to the three major areas of SST work--aircraft design, sonic-boom research, and economic analysis. Because of encouraging recent progress in the program, the committee considered it highly probable that future work on basic technological problems could lead to a commercially profitable SST. But if the financial and development risks underlying the program were to be minimized, much work remained to be done before undertaking the construction of a prototype aircraft.

After receiving the recommendations of his committee, the President announced on July 1, 1965, his determination that the SST program should move into an 18-month phase of accelerated design work aimed at starting prototype construction by the end of 1966. To initiate this phase of the development program, the President requested and Congress appropriated $140 million, increasing threefold the level of funds available. Primary objectives of the 18-month design phase are to:

a. build a sound foundation for realistic estimates of operating performance and development costs.

b. reduce development risks and costs while keeping open the option to accelerate the program in its later phases if warranted by technological progress of the contractors.

c. take advantage of the extensive flight experience programed for several advanced supersonic aircraft during the 18-month period.

d. provide a basis for determining with greater knowledge and precision what work should be done and how to proceed in succeeding phases of the program.

An assessment of the two potential SST contractors' progress toward optimizing their SST designs got underway in mid-November and was completed at year's end. As part of the assessment, models were used in wind-tunnel tests. The intensive study--conducted by 85 Government experts from NASA, FAA, Air Force, and Navy--considered only airframe designs. Engines were not included in the study since each engine company will each build three prototype engines during the accelerated design phase. A report of findings by the Interim Aircraft Design Assessment Group is in preparation.

Subsonic Aircraft Development

FAA continued efforts to improve the efficiency and flexibility of the Nation's air transportation system through participation with the Armed Services in development projects for military aircraft having potential civil applications. Civil certification, in January, of the C-141A STARLIFTER--the first large jet cargo aircraft ever developed for the dual roles of military airlifter and civil airfreighter--climaxed a unique USAF-FAA effort extending from initial design to production. In April, a provisional type-certificate was issued for the Army's CV-7A BUFFALO turboprop transport. A program to fully qualify the BUFFALO for civil use is continuing.

Developments in the field of helicopters and other vertical or short takeoff and landing (V/STOL) aircraft were particularly noteworthy. In January an interagency civil-military task group was formed under the chairmanship of the FAA Administrator to assess the potential of such aircraft for city center to city center operations between major metropolitan areas. Studies were begun to: (1) review the status of V/STOL technology; (2) identify problems related to the use of such aircraft in the national airspace system; (3) analyze short-haul transportation needs; and (4) make recommendations for strengthening the national transportation system by exploiting the intrinsic advantages of ground and air vehicles. A report is scheduled for early 1966.

In related actions, FAA participated in the Army's Advanced Aerial Fire Support System development program, furnishing technical assitance on standards necessary for civil certification of the primary component of the system, a compound helicopter (wings as well as rotor blades). A potential civil application of this new-type air vehicle is used as a high-speed (200-knot) executive transport or utility helicopter. The Army's Flying Crane helicopter (YCH-54A) moved a step nearer civil certification, a prerequisite for Army procurement, with FAA's authorizing a "type inspection" in May.

All three entries, in the Army's closely contested light observation helicopter competition, received FAA civil airworthiness certificates during 1964. Before a winner was named in May 1965, two manufacturers had announced plans to offer their models to civil buyers. On the basis of Army estimates, indicating a four-fold increase in productivity over previously available light helicopters, civil use of these new turbine-powered helicopters will be greatly expanded.

AIRCRAFT SAFETY PROGRAMS

To make the airways safer, FAA conducts programs to put more safety into both the man and the machine. Notable 1965 developments in programs concerned primarily with the human factor include:

a. new and higher certification standards for flight instructors, plus a requirement for biennial requalification on the basis of demonstrated currency and competence or satisfactory performance in the rating.

b. establishment of new standards of medical fitness to govern recruitment and continued employment of FAA's air traffic control specialists, who constitute the Agency's largest employment group by specialty.

c. new pilot-rating regulations, effective in December 1965, designed to match pilot skills more precisely to the complexities of modern high-performance aircraft.

d. continued FAA encouragement of voluntary refresher training for certificated pilots through Agency collaboration with national organizations and educational institutions.

e. launch of Project GAPE (General Aviation Pilot Education) under a contract award. Object of this year-long project, which was announced in July, is to persuade the general aviation segment of the aviation community to upgrade its flight proficiency and knowledge. Some 11,500 different organizations and aviation industry personnel were contacted and requested to cooperate in supporting a nationwide program of accident prevention through a vigorous publicity campaign, displays, meetings, seminars, special conferences, personal contacts, and similar educational activities. Progress reports will be submitted to FAA.

f. successful completion of the second year of FAA's Aviation Mechanic Safety Awards Program, which, through awards to State, regional, and national winners, provides increased recognition to the aviation mechanic and emphasizes his vital role in the safety of flight.

Notable developments in other safety programs include:

a. tests involving natural lightning strikes on protected aircraft equipped with instruments to register intensity and effect. Sponsored by FAA, these tests were also supported by the Weather Bureau, the Atomic Energy Commission, and the U.S. Air Force. Results are under evaluation.

b. fire tests on jet engines for aircraft. Tests were continuing at year's end on a JT3D engine mounted in a 720B nacelle, a powerplant installation widely used in air transport service; these tests will provide a basis for improved fire detectors and better in-flight fire protection. For better fire protection of small jet engines, tests were being conducted on a JT-12 engine pod from a JETSTAR.

c. tests on flammability limits of fuel and air mixtures under actual environmental conditions, undertaken in cooperation with the U.S. Navy at the Philadelphia Navy Yard.

d. development of a specially modified truck incorporating friction-measuring equipment, for studying surface-friction characteristics of selected runways at major airports throughout the country. The vehicle was being tested at year's end.

e. continued research on air turbulence by both the Government and the aviation industry--particularly clear-air turbulence. The most significant finding thus far correlates turbulence-caused aircraft upsets with night or instrument flying. Attention was thus focused on improving aircraft-attitude instruments and the cockpit display presented to the pilot. Improvements of this kind have been made by 17 of the 18 Air Transport Association members.

f. continued research and development effort on both airborne and ground techniques for identifying and displaying clear-air and storm-produced turbulence. Now under study is a considerable fund of data amassed with an airborne temperature-recording device. Being evaluated under operating conditions at an air route traffic control center are two ground equipments developed under contract for presenting "weather" on air traffic control radarscopes. A third ground equipment is under contractual development for use with more advanced radar remoting equipment than that now in use.

g. start of FAA-Weather Bureau tests to evaluate the potential advantages of computerized weather-forecasting techniques. In the tests, the computer makes its forecasts on the basis of data from hourly observations at 73 selected airports, nationwide, plus prestored information on the last decade of climatic history at each of the eight airports receiving these automated probability forecasts.

h. continued efforts to combat the aircraft sabotage problem. Work began on a chemosensing device to develop a practical passive system for detecting concealed explosives.

i. survivable-accident research, or research aimed at eliminating fatalities in the type of accident in which the frame of the aircraft remains intact. Outstanding in this area during the year was the determination of impact data of value to aircraft design engineers in making aircraft interiors safer. Tests showed that the human head, in collision with such objects as instrument panels or seats, can tolerate an impact force of 50 G's, and the nose before fracture, 30 G's; to complement this information, impact data were obtained with special equipment on a variety of aircraft-interior components.

OTHER ACTIVITIES FOSTERING AERONAUTICS

All-Weather Landing

An important milestone toward the ultimate goal of all-weather flying was passed in October 1965 when FAA approved one of the major trunk air carriers for landing operations under weather minimums of 150-foot decision height and 1,600-foot runway visual range (RVR). After satisfactory operation under these minimums for six months, the carrier will be approved for the category II minimums of 100-foot decision height and 1,200-foot RVR. Another major trunk carrier was approved in December and two others are still in the process of qualifying for operations under the minimums of 150 and 1,600.

Since fewer flights will have to be diverted or delayed because of weather conditions, the category II minimums will enable qualifying airlines to maintain greater schedule regularity than is possible under the present landing minimums of 200-foot decision height and 1,800-foot RVR (2,000-foot RVR for four-engine jets). Maintenance of safety standards is being assured by the rigorous requirements the carriers must meet before receiving FAA approval for category II operations--requirements in performance quality of equipment and in the training and proficiency of pilots.

Further, category II operations can take place only at airports that meet the safety standards required. At present, five airports have been approved: Washington's Dulles International, and the airports at Pittsburgh, Oakland, Atlanta, and Louisville.

Achieving the feasibility of category III operations--with landing minimums of zero-zero--continued to be the goal of research and development efforts. Since 1961, tests have been conducted toward this end with a piston-powered Agency aircraft that has made well over a thousand automatic landings. In November 1965, FAA let a contract for the design of an all-weather fully automatic landing system to be tested in a four-engine jet transport. A complete category III ground system, utilizing improved ILS components, is being installed at the Agency's National Aviation Facilities Experimental Center, Atlantic City, N.J.

Long-Range Navigation

FAA continued its close work with commercial air carriers in the evaluation of advanced long-range navigation equipment. Cooperation continued with three U.S. carriers operating over the North Atlantic and the Pacific in refining Doppler radar navigation techniques. An inertial navigation system, which offers the prospect of self-contained navigation in all parts of the world without any need for periodic updating, is being tested by two U.S. air carriers.

International Aviation Research and Development Symposium

FAA's Third International Aviation Research and Development Symposium took place at Atlantic City, N.J., in November 1965, attended by representatives of some 30 countries. Taking as its theme "Automation in Air Traffic Control," the symposium heard technical papers from representatives of leading countries in aeronautical development, and held panel discussions devoted to research and development achievements in the theme area.

FEDERAL COMMUNICATIONS COMMISSION

CHAPTER XII

INTRODUCTION

This year marked the beginning of commercial communications satellite service. EARLY BIRD, a synchronous communication satellite, was launched on April 6, 1965, and regular commercial service between United States and Canada and Western Europe involving telephone, record communications and television programs began on June 28, 1965. The International Telecommunication Satellite Consortium (Intelsat) which owns the space segment of the international global system has shown steady growth and progress. As of December 31, 1965, 48 countries had become members.

The Commission has granted authorization for construction of earth stations in Washington State and Hawaii. NASA and the Communications Satellite Corporation have signed a preliminary agreement under which ComSat would provide needed communications service via satellites for the APOLLO (man to the moon program). These satellites would be owned by the International Consortium. The Commission has authorized the construction of additional advanced satellites and has under consideration an application for construction of three transportable earth stations for use in connection with the APOLLO Space Program.

The Commission is engaged in a number of proceedings to determine questions relating to: (a) the ownership, operation and control of earth terminals; (b) the extent that entities other than communications common carriers should be permitted to contract directly with ComSat for satellite communication services; and (c) the reasonableness of rates established for satellite communication services. The Commission adopted Rules relating to use of radio frequencies to conform to agreements reached by the Extraordinary Administrative Radio Conference (Geneva, 1963) and is continuing to explore means of establishing better communications for aeronautical use, including the possible use of communication satellites. A television network has tendered an application for authority to launch and operate a communication satellite to distribute television programs to its affiliated stations in this country.

The Commission has established an inter-bureau study group to consider and coordinate the various activities of the Commission which relate to satellite communications.

REGULATORY ACTIVITIES

The Commission authorized ComSat to launch into synchronous orbit a satellite, EARLY BIRD, which would make possible the relaying of communications between the United States earth station at Andover, Maine, and European earth stations located in the United Kingdom, France, Germany, and Italy. The satellite was launched April 6, 1965, on June 23 commercial service on a regular basis was authorized for the transmission of voice, record, data, telephoto, facsimile, and television, pursuant to tariffs filed with the Commission, and on June 28 regular commercial service was begun. The Commission permitted the tariffs filed by ComSat for service to United States entities to go into effect, but in order to insure that any economies made possible by the communication satellite system would be reflected in rates charged to the public, the Commission ordered an investigation into the reasonableness of the rates. It further ordered that all revenues obtained by ComSat under the tariff be placed in a deferred credit account until the conclusion of the investigation. The investigation is continuing.

Later in the year the Commission authorized the construction of another satellite, similar in all respects to EARLY BIRD and to be used in case of failure of that satellite. Construction is scheduled to be completed early in 1966.

The Commission also authorized the construction by ComSat of two additional earth stations--one in the State of Washington and the other in Hawaii--in order that communication satellite service could be provided in the Pacific areas. The authorization was granted pursuant to an interim policy adopted by the Commission and is limited to the early years of the basic system. The Commission also has approved an application for four additional satellites and has under consideration an application for three transportable earth stations which will be used in connection with the APOLLO Space Program.

The APOLLO network is to be composed of earth stations located at Andover, Maine; Brewster Flat, Washington; Paumalu, Hawaii; Carnarvon, Australia; Gran Canaria Islands; Ascension Island; and aboard three ships provided by the United States Government. One of the four satellites is to be positioned over the Atlantic Ocean, another over the Pacific Ocean. The remaining two satellites are to be used in case of failure of one of the operating spacecraft. The satellites will be owned by the International Telecommunications Satellite Consortium which will provide the communication facilities for the APOLLO Program. The communications capacity of the system will be such that the requirements of the National Communications System, which is responsible for the communications needs for the APOLLO Program, can be met, as well as providing approximately 100 voice grade circuits for other commercial uses.

The Commission adopted a Notice of Inquiry in June of 1965 inviting comments of all interested parties in regard to the question of who in addition to communications common carriers could or should be authorized to obtain telecommunications services directly from ComSat. The Commission is now considering the comments and expects to make a determination shortly. The determination can have significant effects on the structure, economics and operations of the telecommunications system of the United States.

Procurement Actions

The Communications Satellite Act of 1962 requires the Commission to maintain maximum competition in the procurement of equipment and services by ComSat for the global commercial communications satellite system, including satellite terminal stations. The Commission's Rules and Regulations, which establish procedures to carry out its statutory responsibilities, have been in effect for nearly two years.

Since January 1, 1965, the Commission has reviewed procurement procedures including nine prime contracts aggregating in value approximately sixteen million dollars and one major subcontract of $52,500, all of which were awarded after competitive negotiation and bidding. Approximately 165 different U.S. firms including small business concerns, in all major areas of the country, were solicited before the awards were made. In addition, 74 foreign firms were invited to submit bids. The contracts awarded involved various aspects of the Global Commercial Communications Satellite System including satellite terminal stations; a launch trajectory simulation program; architectural and engineering services for the Northwest United States and Hawaiian satellite terminal stations; high power amplifiers for the Andover, Maine, satellite terminal station; general research and study programs; and spacecraft and other equipment for the APOLLO Program.

ALLOCATION OF FREQUENCIES FOR SPACE COMMUNICATIONS AND RADIO ASTRONOMY

In May 1965, the Commission adopted a Report and Order in Docket 15722 amending Part 2 of its Rules so as to conform, to the extent practicable, with the Geneva (1959) International Radio Regulations, as revised by the Geneva (1963) Extraordinary Administrative Radio Conference on frequency allocations for space radiocommunication purposes and radio astronomy. At the same time the Commission adopted another Report and Order in Docket 15723 amending Parts 21 and 25 of its Rules so as to provide for the shared use of the frequency bands 3700-4200, 5925-6425, 7250-7750 and 7900-8400 Mc/s by the Fixed, Mobile and Communication-Satellite Services. These rule parts govern the Domestic Public Radio Services (other than maritime mobile) and Satellite Communication, respectively. Notices of Proposed Rule Making in both of these Dockets had been issued for public comments in December 1964, after appropriate inter-agency coordination.

More specifically, the Rule amendments effected in Docket 15722 consisted primarily of modification to the Table of Frequency Allocations contained in Part 2 of the Commission's Rules within the framework of internationally adopted allocation changes. Also included were revised definitions for use in the field of space radiocommunication and provisions for the domestic implementation of an internationally adopted notification procedure whereby international recognition could be afforded individual radio astronomy operations. Docket 15723 resulted in the adoption of sharing criteria and technical limitations intended to provide adequate protection against mutual interference so as to permit the shared use of certain microwave bands by the Fixed, Mobile and Communication-Satellite Services. Such protection is based primarily on power limitations, limitations on minimum angle of elevation for earth stations, appropriate geographic separation distance and advance coordination of assignments, where required, and is consistent with internationally agreed criteria.

Work is continuing both nationally and internationally on technical and operational questions relating to space systems and radio astronomy. Commission staff representatives participated in this work as members of the U.S. Delegation to the Interim Meeting of Study Group IV of the International Radio Consultative Committee (CCIR) of the ITU convened in Monaco in February 1965. The results of that meeting will be further refined in preparation for the XIth Plenary Assembly of CCIR scheduled to convene in Oslo, Norway, in June 1966.

EXPERIMENTAL DEVELOPMENTS

The Commission authorized the construction of an experimental earth station in Arkansas for the purpose of performing experimental operations relating to satellite communications, developing "multiple access" capability, and testing new system concepts and modulation schemes.

The progress to date in the implementation of the Communications Satellite Act of 1962 has reached the point where the establishment of a global commercial communications satellite system in the near future is assured. The Commission believes it appropriate now to focus attention on possible future developments in the field of communication satellite technology. To this end the Commission proposes to amend its Rules and Regulations to establish procedures for the filing and processing of applications which seek authorization to engage in developing new techniques, and in the development and testing of new equipment intended for use in communication satellite service.

AERONAUTICAL DEVELOPMENTS

The Commission, in discharging its statutory responsibilities with respect to non-government uses of radio for aviation, prescribes the manner and conditions under which frequencies may be assigned for aeronautical telecommunications purposes. Such purposes include flight test telecommunications and telemetry functions used in the development and production of missiles, rockets and satellites as well as aircraft. Additionally, the Commission assigns frequencies to aircraft radio stations, aeronautical enroute, radionavigation, aeronautical advisory and other stations comprising the aviation radio services.

The Commission has continued actively working with other government agencies and the aviation industry toward transition from the present double sidebands to a single sideband voice communications in the aeronautical high frequency. Regular domestic use of high frequency air ground communications in the 48 contiguous states was discontinued January 1, 1965. It is expected, however, that both HF and VHF will be required for the next several years in Alaska, Hawaii and the U.S. island possessions and on the international air routes. The use of satellites is now under consideration as one possible method of relieving loading on existing high frequency facilities particularly on the long over-water air routes.

Development of the use of VHF aeronautical enroute system utilizing satellite relay techniques began during 1964. An application was granted for special temporary authority for developmental operation to test aeronautical communication on the Pacific air route by relay through satellite SYNCOM III. The tests by the aeronautical industry conducted under this authorization have demonstrated the feasibility of this type of communication. The Commission is presently working with industry, NASA, and other government agencies toward further testing of aviation telecommunications utilizing the Applications Technology Satellite (ATS) and as part of the ATS/VHF program. The Second Session of the two part Aeronautical Extraordinary Administrative Radio Conference (EARC) of the International Telecommunication Union (ITU) to consider revision of the high frequency allotment plan for aeronautical mobile service and related provisions of the Radio Regulations, is scheduled to convene March 14, 1966. The United States recommendations to the Second Session will include the results of studies and tests and planning toward the utilization of space radiocommunication techniques by the Aeronautical Mobile (R) Service.

UNITED STATES
INFORMATION AGENCY

CHAPTER XIII

INTRODUCTION

For USIA, which tells America's space story to the world as part of its mission, 1965 was a busy year. As the space record of the year unfolded, USIA through the Voice of America and its wireless, pictures, and feature services reported it swiftly and widely. This vital story was carried abroad in other forms through motion pictures, television, exhibits, libraries, pamphlets, book translations, and cartoon strips.

In the same year, APOLLO hardware for a manned landing on the moon began reaching test stations; international television transmission on EARLY BIRD, inaugurated by ComSat, became commonplace; NASA's international space programs were expanded, and the United States sent its astronauts abroad to tell other people first hand about the discoveries in space. U.S. Information Service staffs at 214 posts in 103 countries worked throughout the year to carry this story to media offices and youth groups, and to the scientific, educational, and governmental communities.

GUIDELINES

These precepts served to guide USIA in treating space activities during the year:

a. the U.S. space program is broadly based, follows long-range objectives, seeks to develop proficiency in all key areas, and evidences U.S. world leadership in science and technology.

b. it is U.S. policy to use outer space for peaceful purposes, to put space to practical use for the benefit of mankind through space applications, and through international programs to assist other countries in the development of space technology.

c. the United States cooperates with other nations in space. Towards this objective the United States in 1965 concluded new agreements with Argentina and Brazil for an experimental inter-American weather research network; agreed to launch a West German-designed-and-engineered scientific satellite, and to jointly publish research in space medicine and biology with the Soviet Academy of Sciences. A new agreement was also signed with India, and Canadian and French earth-orbiting satellites were launched by NASA.

d. it is U.S. policy to conduct manned space operations openly for all communications media, and when the data obtained has been analyzed to make it available to the public, including the press and the scientific community.

PROBLEM AREA NEUTRALIZED

The fact that the Soviets launch larger manned spacecraft than the United States ceased to be the inhibiting factor conditioning foreign opinion of the United States in space. The Soviets again launched a two-man flight with VOSKHOD 2 and accomplished the first walk in space. But with the flights of RANGER 8 and 9, MARINER IV, the successive GEMINIS, and the extra-vehicular performance, the U.S. space program had hit its own high level of performance. A USIA report on world press reaction to GEMINI 5 commented: "Few (editorialists) doubted that the U.S. had now moved into a position of formidable challenge to, if it had not actually overtaken or surpassed, the U.S.S.R. in space."

TREATMENT

Manned Flight

The GEMINI flights are portrayed as the second phase of a three-part program (MERCURY, GEMINI, and APOLLO) to land U.S. astronauts on the moon by 1970. As the most ambitious and dramatic part of the space program, and that with the greatest impact abroad, manned flight receives across-the-board attention from USIA media.

Thus the Agency's resources were mobilized to tell the story of GEMINI 3, 4, 5, 6, and 7. Treatment of GEMINI 4, here related, tells the story. Voice of America's worldwide network transmitted detailed coverage in English for seven and one-half hours before launch and three hours during descent and recovery. Simultaneously, transmissions in Spanish and Portuguese were beamed to 400 stations in 18 Latin American countries, while 35 other language services carried bulletins and regular accounts. Special teams at Cape Kennedy, Houston, and Washington kept audiences up to date, and backgrounded the flight by 19 special stories about equipment carried aboard the spacecraft such as space foods, suits, and oxygen guns and six 30-minute special programs.

USIA's wireless service carried 18 pre-launch stories, including by-liners by astronauts and wives, and 42 post-launch stories, from lift-off to splash-down. An elaborate pre-flight package with photographs explaining the GEMINI program was in the hands of posts in time for lift-off. Posts also received 24 pictures and 5 color transparencies covering pre-flight and lift-off, and 42 pictures and 5 color photographs of recovery, to be reproduced and placed in the local press. African posts got 5 plastic engravings ready for printing, and 5 more in stencil for mimeographed bulletins. A 6-picture color poster showing the blast-off and walk-in-space was given world distribution. As further education on GEMINI in advance of the flight, 2,000 copies of a 4-color, 4-panel exhibit, "Man Maneuvers Moonward," was distributed to all posts, as was a standard lecture on the GEMINI program with 36 color slides, for use by non-Americans in schools, clubs, and local groups.

The GEMINI 4 story was carried to television audiences in 47 countries in two pictures, a 10-minute feature, "The Walk in Space," and a half-hour program, "Conversation with Astronauts White and McDivitt," prepared in English, Spanish, French, and Arabic. A USIA color film, "The Flight of GEMINI 4," was seen in 110 countries, having been prepared in 21 languages. A black-and-white newsreel of the same event, "U.S. Astronaut 'Walks' in Space," was prepared in 23 languages with 663 prints exhibited in 109 countries.

RANGER 8 and 9

The extraordinary success of the RANGER 8 and 9 spacecraft in photographing the moon's surface was a high point of USIA coverage of the year in space. The thousands of pictures returned by the two RANGERS were portrayed as a remarkable achievement for U.S. space technology providing space scientists with the best information to date for planning the manned lunar landing.

Voice of America kept the "moon shots" alive from launch to impact, while the Agency's photo service put the RANGER pictures into the hands of posts within two to three days of their release. The wireless service sent 18 stories totaling 8,340 words on both RANGERS. USIA Public Affairs Officers arranged for presentation and press coverage on the NASA RANGER picture folios, given to key scientists and governmental officials in many countries. "Moonshot," a pamphlet covering the two RANGER flights, was sent out first on the wireless file for newspaper use, and, combined with pictures, printed in five languages for 350,000 copies.

MARINER 4

During a year marked by major achievements, only the walk in space of GEMINI 4 equaled in impact MARINER 4 and its pictures of the Martian surface. The reporting of the environment of Mars by MARINER 4's sensors was hailed widely through the world's press. A Paris daily, L'Aurora, struck a common chord when it commented: "A dazzling scientific feat. All men of our time are entitled to share the pride of the Americans." MARINER IV was presented to world audiences as perhaps the most successful experiment in space so far, and one of the outstanding scientific feats of all time.

TITAN 3-C and MANNED ORBITING LABORATORY (MOL)

The first test of the Air Force's TITAN 3-C, the world's most powerful known space booster to date, came early in the year, and the decision to develop the MANNED ORBITING LABORATORY (MOL), which the TITAN will put into space, came later. World audiences were told that the TITAN 3-C is the first military booster designed from the outset for space missions, and that by strengthening the free world it will help to keep the peace. MOL is to be neither a weapon nor a weapon's carrier and in no way contradicts America's peaceful purposes in space. Rather, it aims to increase knowledge of man's usefulness in space and to relate this ability to free world defense.

U.S. Astronauts Abroad

U.S. astronauts, sent abroad for the first time when President Johnson dispatched astronauts McDivitt and White to the Paris Air Show, proved to be an effective foreign policy resource. An observer on the scene reported: "The visit, completed 51 hours after it began, changed the whole atmosphere of the Air Show. It reversed the U.S. image and generated a wave of good feeling toward the United States."

So that other countries could learn from the astronauts themselves what the United States had learned in space, the President dispatched astronauts Cooper and Conrad to the International Astronautical Congress in Athens, Greece. The astronauts carried their Presidential mission from there to Turkey, Ethiopia, Kenya, the Malagasy Republic, Nigeria, and the Canary Islands, visiting NASA tracking stations in the latter three areas. Voice of America carried details of the astronauts' reception to African audiences, while U.S. Information Service staffs prepared local arrangements and press coverage.

Press and Publications

For the Press Service space science has been a major theme for affirming U.S. scientific and technological leadership. The wire service in 1965 moved 411 stories totaling over 137,000 words on MARINER IV, TIROS IX and X, the ORBITING SOLAR OBSERVATORY, RANGER VII and IX, SATURN-PEGASUS, GEMINI 2 through 7, SNAP 10-A, EARLY BIRD, EXPLORER, TITAN II and III, ComSat System, and other space projects--or an average of over one a day. Seven special advance packets were produced, the GEMINI 5 packet containing 10 stories, 5 pictures, orbital pass charts and visibility predictions.

Space science accounted for a good part of the Agency's pamphlet production, an advance pamphlet, "Mariner to Mars," being printed in 5 languages for 163,000 copies, and "Journey to Mars," covering photos and data from the flight, being printed in English for 10,000 copies, with vernacular orders to follow as the posts place them. Six other space pamphlets included "Destination the Moon," telling the story of PROJECT APOLLO, "GEMINI 6 and 7," in preparation at the year's end, and "Walk in Space," supplied by NASA, which has already run to 45,000 copies in four languages with more to follow.

Photo service on space science was very wide. Each black and white subject, for instance, involves 187 prints and 87 negatives spread among 151 posts according to their needs. Thus the MARINER 4 flight was covered in 32 black and white subjects, in addition to color photographs and plastic engravings, which have a somewhat similar distribution. Additionally, the Photo Bulletin, a monthly offset sheet from which posts order, carried 23 photos on APOLLO, 4 on GEMINI 2, and 15 on various other space science items. A new product specially designed for African posts carried 5 stencils on GEMINI 4 and 5, for reproduction on mimeograph bulletins. A 4-color poster on Astronaut White's walk in space was printed in 60,000 copies in 7 languages.

Amerika Illustrated in both Polish and Russian editions carried stories on MARINER IV, RANGER IX, GEMINI 4 (including a 10-page color spread), and EARLY BIRD. Al Hayat fi Amerika, the Agency's Arabic-language magazine, carried a wrap-around cover on space science stations tied to a story on "Getting Ready for the Leap to the Moon," among other features. Cartoons in the "It's a Fact" series were carried on all the GEMINI flights, on MARINER IV, astronauts' gear and garb, EARLY BIRD satellite, and other projects; so did "True Tales," a comic strip series. These are reproduced in offset and in plastic plates and appear in hundreds of newspapers overseas.

Television

The Agency produced a number of features to tell the space story abroad.

"RANGER IX," in English only, was a 20-minute recap of the flight, climaxing with the pictures transmitted directly to U.S. television screens. "Moonport USA" was a 30-minute feature examining the Cape Kennedy moonport through the eyes of a project engineer and his young son. "A Day in March" viewed a GEMINI flight at Cape Kennedy through the working press and nearby onlookers, stressing the openness of U.S. space operations. A half-hour feature, "Eight Months to Mars," reported extensively on the MARINER IV mission. "GEMINI VI: Halfway Point" was in the hands of posts abroad before the flight and explained the rendezvous and docking mission. All of these pictures were sent out in three or four language versions. Space events were topically covered throughout the year in "Science Report," a fortnightly 15-minute review of events in American science distributed in 53 countries in more than three language versions.

Radio

The Voice of America, through its regular and special topical coverage of space, plus special reports that treat of space events in detail, is one of the Agency's chief links with foreign audiences in this area.

Motion Pictures

"Above the Earth and to the Moon," an original Agency production that treated of both the walk in space of GEMINI 4 and the RANGER 9 moon reconnaissance was released in 26 languages in 113 countries, and in Mexico alone was seen by an audience of 4 million. "Destination Man," another Agency production exploring the limits of man's adaptability to space, won an award at a Belgrade festival of scientific films and was distributed in 101 countries. Two NASA films, "Lunar Bridgehead" and "Project GEMINI: Mission Concept," also were used, the latter film being booked heavily, for instance, by German observatories and scientific organizations.

Exhibits

An estimate of the Agency's worldwide viewers of its 19,600 printed exhibits on the U.S. space program and 70 travelling exhibits this year is conservatively placed at 18,000,000. These were seen in locations ranging from Moscow to Kathmandu, from Helsinki to Mogadiscio, from Saigon to Buenos Aires, from Ankara to Tokyo. Three hundred USIA outlets around the world showed or arranged showings by local organizations of 1965's production of four printed exhibits issued in 6,100 copies and 37 sets of more imposing travelling exhibits, and kept previous years' production in circulation as well.

Information Centers

Under the Book Translations Program, more than 300,000 copies of 27 books dealing with space have been published in 9 languages. More than 1,000 copies of books offered posts on "The U.S. In Space" have been requested for library, presentation, and for translation. Eight titles on space offered in various Current Recommended Reading Lists resulted in 1,107 requests from posts. Posts also requested and received 33 government publications on space and a lecture packet on GEMINI complete with color slides, while an English-Teaching Conversation Packet on practical benefits of the U.S. space program is in preparation.

ARMS CONTROL AND DISARMAMENT AGENCY

CHAPTER XIV

INTRODUCTION

Space considerations are very important in the pursuit of United States arms control and disarmament objectives.

The most urgent immediate objective of the Arms Control and Disarmament Agency (ACDA) is preventing the spread of nuclear weapons. The implementation of this objective applies not only to the face of the earth but also to the dimension of space. It is United States policy to oppose extension of the nuclear arms race to outer space.

In promoting our national security through balanced and safeguarded arms control and reduction agreements, space also affords a medium which could be utilized in verifying compliance with such agreements.

The efforts of ACDA, both in the negotiating and research fields, involve these goals.

DISARMAMENT PROGRAMS

Preventing the Extension of the Arms Race to Space

The Resolution of the UN General Assembly on October 17, 1963, which was adopted unanimously, expressed the intention of all parties to refrain from stationing weapons of mass destruction in outer space. ACDA research played a part in the formulation of the U.S. position on this Resolution.

Additional measures aimed at strengthening this Resolution and at increasing its credibility as space technology improves are also under investigation.

Through its research program, the Agency has contracted for continuing studies of the technical aspects of a prohibition of weapons of mass destruction in orbit. Verification questions based on unilateral monitoring capability opposed to the continually improving capability of adversary nations are being examined in detail to assure that existing and planned space-tracking systems will be able to detect and identify deployment of any significant space weapons system in violation of the UN Resolution.

Implications for Space Programs of a Freeze on Strategic Weapons

The U.S. has proposed, at the Eighteen Nation Disarmament Conference and other forums, that major powers explore the possibility of a freeze of strategic aircraft and missiles capable of delivering nuclear weapons. Some type of freeze agreement could provide a first step in halting and possibly turning downward the present strategic weapons race. Under such an agreement, production and deployment of these delivery vehicles would be strictly controlled. A particular issue for study has been the requirement to devise inspection means which would guard against violations of prohibitions on improved weapon system characteristics without interfering with varied and active peaceful space programs.

Although the Soviet reaction to date to this freeze proposal has been negative, the Agency continues to study variations of this proposal and the verification systems required to protect our national security interests. In addition to ground inspection, the potential advantages of inspection satellites for verifying the more conspicuous aspects of strategic weapon operations are under continuing investigation.

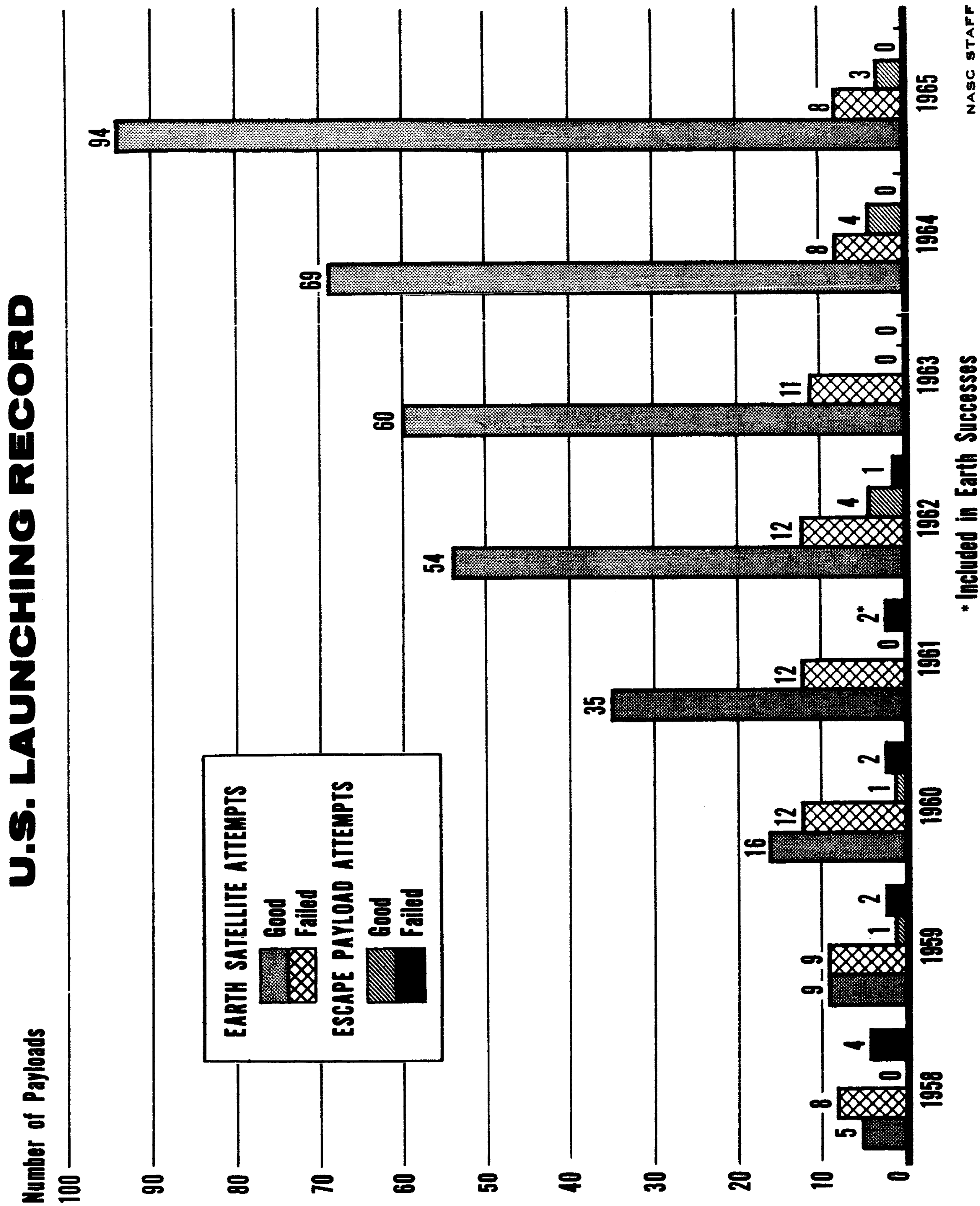
In particular, the following areas have been investigated: the restriction and control of flight testing for military space programs; the implications of future weapons technology; and the possible conversion of space boosters to ballistic missiles.

Use of Space Vehicles for Inspection and Verification

During the past year additional VELA satellite launchings by DOD augmented the operation, underway since 1963, for creating a system of satellites designed to detect nuclear test violations in space of the Limited Nuclear Test Ban Treaty. ACDA cooperated in this and other ARPA-developed programs aimed at increasing U.S. verification capabilities associated with this treaty.

Looking to the future, ACDA is investigating the potential contributions which inspection satellites might make to inspection and verification systems associated with various arms control measures. Studies have been carried out on technical capabilities of various possible inspection vehicles and the manner in which these vehicles might be used.

In addition, ACDA is working cooperatively with NASA, using the talent residing in NASA centers, to explore the inter-relationship of non-military space programs with arms control measures and their verification. These studies have also looked at how developing space technology might be influenced by arms control measures, and at identifying any potential conflicts. In this way it is hoped that the full significance of restrictions intended to control weapon developments will not hamper in any way peaceful space programs.


U.S. LAUNCHING RECORD
Number of Payloads
100
90
80
70
60
50
40
30
20
10
0
EARTH SATELLITE ATTEMPTS
Good
Failed
ESCAPE PAYLOAD ATTEMPTS
Good
Failed
1958
5
8
0
4
1959
9
9
1
2
1960
16
12
1
2
1961
35
12
0
2*
1962
54
12
4
1
1963
60
11
0
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1964
69
8
4
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1965
94
8
3
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* Included in Earth Successes
NASC STAFF

UNITED STATES LAUNCHING RECORD

Year	Earth Satellite Attempts Success	Failure	Escape Payload Attempts Success	Failure
1957	0	1	0	0
1958	5	8	0	4
1959	9	9	1	2
1960	16	12	1	2
1961	35	12	0	2*
1962	54	12	4	1
1963	60	11	0	0
1964	69	8	4	0
1965	94	8	3	0
Total	342	81	13	11

Notes:

1. Information contained in this table is drawn from unclassified sources and is believed to be complete and accurate in keeping with the definitions given below.

2. Numbers are given in terms of identified separate payloads placed in Earth orbit or sent to the Moon or into solar orbit. A few launchings have put up more than one payload. If these payloads were intended to separate from each other in flight, they are counted individually even though in a limited number of cases such separation failed to occur. A payload is defined as an object put into orbit or sent away from the Earth to accomplish some specific research or application purpose and to return data to Earth. Typically, a payload transmits telemetry, but not always (e.g. ECHO which carried only a radio beacon). Some rocket casings may carry radio beacons, but limited data return incidental to putting up a payload does not classify these as payloads in their own right.

3. The sole criterion of success or failure used for the purpose of this table is that of attaining Earth orbit, or escape to the Moon or solar orbit as appropriate to the column indicated. Some payloads reached orbit or escaped without returning as much data as planned; other payloads failed to reach orbit or escape, yet returned useful data at least briefly.

4. The corresponding data for number of launchings attempted (the count without reference to multiple payloads) are the same as given above except in the Earth orbital category for 1959 (8 failures), 1960 (15 successes and 11 failures), 1961 (29 successes), 1962 (48 successes and 6 failures), 1963 (38 successes and 8 failures), 1964 (53 successes and 7 failures), 1965 (60 successes and 7 failures), making totals of 257 orbital launch successes, 13 escape launch successes, 68 orbital launch failures, and 11 escape launch failures, for a grand total of 347 launch attempts (2 escape failures were orbital successes).

5. Data quoted include 2 U.S. payloads with British experiments, two Canadian payloads launched by the United States, one French payload launched by the United States, and one Italian payload launched by an Italian crew from U.S. territory.

*These failed to go to escape as intended, but did attain Earth orbit and are in those totals.

NASC Staff

SUCCESSFUL U.S. LAUNCHES -- 1965

[See explanatory notes at end of table.]

Launch Date Name Designation Vehicle	Payload Data	Apogee and Perigee (in statute miles) Period (minutes) Inclination to Equator (degrees)	Remarks
Jan. 15 DEFENSE 2A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	265 117 90.5 74.94	Decayed February 9, 1965.
Jan. 19 DEFENSE 3A Thor Altair	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	516 286 97.6 98.77**	Still in orbit.
Jan. 19 GEMINI II System Test Titan II	Total weight: 6,883 lbs. (includes reentry and adapter modules). Objective: Flight-qualify the GEMINI spacecraft as integrated system for manned spaceflight. Payload: 19' x 7-1/2' 2-module bell-shaped spacecraft, containing 2 simulated (electronic) crewmen; guidance and control equipment; 4 cameras; 1 HF and 1 UHF transceiver, high and low frequency telemetry transmitters, tracking and recovery communications; fuel cell; environmental control system; reentry and recovery systems.	Orbit not intended.	Suborbital flight confirmed spacecraft readiness for manned flight; reached altitude of 98.9 mi., top speed of 16,708.9 mph; landed in Atlantic 2,127 mi. downrange, only 16 mi. short of aiming point; was picked up by U.S.S. Champlain, following a 19 minute flight.

Jan. 22 TIROS IX 4A Thor Delta	Total weight: 305 lbs. Objective: Test new cartwheel configuration and operating mode to be used in future operational weather satellites. Payload: 22" x 42" cylindrical 18-sided polygon, containing 2 TV cameras with 104° lens, photo storage, and 2-sec.-scan transmission system; control system and horizon scanners; 9,100 n-on-p solar cells; 63 nickel-cadmium batteries.	1,600 440 119.2 96.41**	Complicated 3-dogleg maneuver put TIROS IX in near-polar orbit to enable global weather coverage; 11-sec. extra burn of Delta 2nd stage caused elliptical orbit instead of 460-mi. circular one. Cartwheel operational mode was a success, as were new components. One camera ceased operation April 1965. Still in orbit.
Jan. 23 DEFENSE 5A Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	152 89 89.0 102.50**	Decayed January 28/29, 1965.
Jan. 28 DEFENSE Probe Blue Scout Jr.	Total weight: Not stated. Objective: Intended to measure the Earth's magnetic field to an altitude of 24,000 miles. Payload: Sensors, batteries, and telemetry equipment.	Orbit not intended.	Second stage malfunctioned and fourth stage did not fire. The payload is estimated to have fallen about 5,500 miles away, southwest of Ascension.
Feb. 3 OSO II 7A Thor Delta	Total weight: 545 lbs. Objective: Continue OSO I studies of solar X-ray, gamma ray, and ultraviolet emission, with added capability to scan entire solar disc and part of corona. Payload: Two-part spacecraft structure; top part a 22"-radius semicircular sail continuously pointed at the Sun and containing 3 experiments, 1,860 n-on-p solar cells; lower part a 44" x 9"	374 287 96.4 32.86	6 of 8 Sun-study experiments functioned well. OSO II contained parts from OSO-B, damaged April 1964 in testing accident. Satellite was turned off in November 1965, after exceeding its 6-mo. life expectancy by 50% and returning some 9,020,000,000 bits of data. Still in orbit.

	9-sided revolving wheel containing 5 experiments, controls, telemetry, recorder, and batteries.		
Feb. 11 DEFENSE 8A Titan IIIA	Total weight: 11,500 lbs., including transtage of 7,000 lbs. and ballast of 1,070 lbs. Objective: Development of space flight techniques and technology. Payload: Ballast, and diagnostic telemetry equipment.	1,737 1,721 145.6 32.15	Still in orbit. The transtage went through multiple firings to change the orbit as planned.
Feb. 11 LES I 8C Titan IIIA	Total weight: 69 lbs. Objective: Development of space flight techniques and technology. Payload: Experimental communications satellite.	1,740 1,722 145.7 32.15	Still in orbit. Intended to be flown to an apogee of about 13,000 miles, but instead stayed in circular orbit when its solid rocket motor did not fire.
Feb. 16 PEGASUS I 9A Saturn I (SA-9)	Total weight: 23,700 lbs., (including 3,200 lb. PEGASUS, 14,500 lb. S-IV 2nd stage, 2,700 lbs. support structure, 2,600 lb. instrument unit, and 700 lb. propellant). Objective: Study distribution, size, and velocity of meteoroids in near-Earth orbit; continue development of Saturn I launch vehicle. Payload: 96' (when unfolded in orbit) x 14' unfolding wings, composed of electrically charged panels sensitive to meteoroid hits, with center section containing motor for unfolding wings, telemetry, solar cells, batteries; all this affixed to 41-1/2'-long S-IV 2nd stage of the Saturn launch vehicle.	453 308 97.0 31.73	Boilerplate APOLLO separated on schedule, PEGASUS I deployed its wings and by September 1965 had recorded meteoroid hits at rate of 44 per sq. meter per year. SA-9 vehicle performed excellently, marking 8th successful Saturn I flight in 8 attempts. Still in orbit.

Feb. 16 APOLLO BP 16 9B Saturn I (SA-9)	Total weight: 10,000 lbs. Objective: To test separation techniques; to provide ballast; to measure total vehicle dynamics; and to provide a shroud for PEGASUS. Payload: Boilerplate APOLLO.	453 309 97.1 31.76	Still in orbit.
Feb. 17 RANGER VIII 10A Atlas Agena B	Total weight: 808.8 lbs. Objective: By means of close-in photography, contribute to scientific understanding of the lunar surface as well as support for the SURVEYOR and APOLLO soft-lunar-landing programs. Payload: 15'-wide and 10'4"-tall (cruise position, with solar panels extended) structure. Hexagonal base contains conical midcourse motor, retro-rocket; other elements are command system, 1 radio receiver, 1 radio receiver and 3 transmitters, telemetry system, 4 batteries, 6 TV cameras, 9,792 solar cells, 2 antennas, attitude-control system.	Impacted on Moon.	RANGER VIII transmitted to Earth 7,137 close-in photos of the Moon's maria before impacting on the Moon Sea of Tranquility February 20, 1965, after excellent flight. Photo time was last 23 min. of flight (compared with last 17 min. for RANGER VII) to provide first photos of a scale comparable to those obtainable from Earth. Results indicated the Sea of Tranquility was similar in structure to Sea of Clouds photographed by RANGER VII, suggested surface had consistency of crunchy snow.
Feb. 23 ASSET VI Reentry Test Thor Delta	Total weight: 1,175 lbs. Objective: To test materials for future lifting body reentry designs. Payload: A winged craft with 2,000 heat sensitive spots, special heat sensitive paints, sensors, and telemetry equipment.	Orbit not intended.	Climbed 40 miles high and landed 2,750 miles away after a 30 minute flight. Much telemetry returned. Intermittent radio signals received after the landing but the search to make a pickup was unsuccessful.

Feb. 25 DEFENSE 13A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	228 111 89.9 75.07	Decayed March 18, 1965.
Mar. 9 GREB VI 16A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Solar radiation measuring instruments.	585 562 103.5 70.06	Still in orbit.
Mar. 9 GGSE II 16B Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Gravity gradient stabilization experiment.	583 564 103.5 70.06	Still in orbit.
Mar. 9 GGSE III 16C Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Gravity gradient stabilization experiment.	582 564 103.5 70.08	Still in orbit.
Mar. 9 SOLRAD 16D Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Solar radiation measuring instruments.	583 564 103.5 70.08	Still in orbit.
Mar. 9 SECOR III 16E Thor Agena D	Total weight: 40 lbs. Objective: Development of space flight techniques and technology. Payload: Geodetic satellite.	583 563 103.5 70.11	Still in orbit.
Mar. 9 OSCAR III 16F Thor Agena D	Total weight: 33 lbs. Objective: Development of space flight techniques and technology. Payload: Amateur radio communications satellite.	583 564 103.5 70.08	Still in orbit. Amateurs in 30 countries transmitted through the 25 available channels in the satellite.

Mar. 9 SURCAL 16G Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Calibration satellite for Spasur System.	583 564 103.5 70.08	Still in orbit.
Mar. 9 SURCAL 16H Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Calibration satellite for Spasur System. (Dodecahedron shape).	585 562 103.5 70.08	Still in orbit.
Mar. 11 DEFENSE 17A Thor Able Star	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	568 127 96.4 89.97	Decayed June 14, 1965.
Mar. 11 SECOR II 17B Thor Able Star	Total weight: 40 lbs. Objective: Development of space flight techniques and technology. Payload: Geodetic satellite.	642 177 97.9 89.99	Still in orbit.
Mar. 12 DEFENSE 19A Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	151 97 88.5 107.6**	Decayed March 17, 1965.
Mar. 18 DEFENSE 21A Thor Altair	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	469 328 97.5 99.03**	Still in orbit.

Mar. 21 RANGER IX 23A Atlas Agena B	Total weight: 808.8 lbs. Objective: By means of close-in photography, contribute to scientific understanding of the lunar surface as well as support for the SURVEYOR and APOLLO soft-lunar-landing programs. Payload: 15'-wide and 10'4"-tall (cruise position, with solar panels extended) structure. Hexagonal base contains conical midcourse motor, retro-rocket; other elements are command system, 1 radio receiver and 3 transmitters, telemetry system, 4 batteries, 6 TV cameras, 9,792 solar cells, 2 antennas, attitude-control system.	Impacted on Moon.	RANGER IX transmitted to Earth 5,814 close-in photos of the Moon's mountains and craters before impacting the Moon's crater Alphonsus March 24, 1965, only 4 mi. off target. Network TV broadcast "live" photos for last 10 min. of flight. Results suggested parts of lunar highlands might be harder and smoother than the maria but that crater floors might be dangerously soft. This was final RANGER flight.

Mar. 23 GEMINI III 24A Titan II	Total weight: 7,111 lbs. (includes reentry and adapter modules). Objective: Demonstrate orbital manned flight capability of GEMINI spacecraft, including maneuver in orbit and controlled reentry and landing. Payload: 18'5" x 10' 2-module bell-shaped spacecraft, containing 2 astronauts; guidance and control equipment; 2 cameras; 1 HF and 1 UHF transceiver, high and low frequency telemetry transmitters, tracking and recovery communications; batteries; environmental control system; reentry and recovery systems.	139 100 88.3 32.50	GEMINI III, 1st U.S. two-man spaceflight and 1st manned flight in the GEMINI program, successfully flew the planned 3 orbits of the Earth, made world's first piloted orbital changes (in 2-in plane maneuvers, dropped apogee from 139 to 105 mi., later dropped perigee from 99 to 52 mi.; in out-of-plane maneuver, changed plane by .02°). Astronauts Virgil I. Grissom and John W. Young made controlled reentry and landing, March 23, 1965, impacting in the Atlantic 58 mi. short when spacecraft developed less lift than expected, were picked up by helicopter. Flight duration was 4 hrs., 53 min.
Mar. 25 DEFENSE 26A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	147 112 88.9 96.02**	Decayed March 4/5, 1965.
Mar. 30 DEFENSE Probe Blue Scout Jr.	Total weight: 47 lbs. Objective: To measure variations in trapped radiation in Earth's magnetic fields. Payload: Sensors, batteries, and telemetry equipment.	Orbit not intended.	Climbed about 9,700 miles up on a 4-hour flight, then fell in the Indian Ocean. Met mission objectives.

Apr. 3 SNAPSHOT I 27A Atlas Agena D	Total weight: 970 lbs. Objective: To test the operation and life of a remotely controlled nuclear reactor power source in space; also to test an ion propulsion unit. Payload: SNAP 10A nuclear reactor power supply and ion propulsion unit.	820 788 111.5 90.17**	Still in orbit. Twelve hours after launch it was producing over 600 watts of power. On May 20, 1965, the reactor shut down automatically for some reason external to its own functioning. The ion propulsion system was not adequately operated.
Apr. 3 SECOR IV 27B Atlas Agena D	Total weight: 40 lbs. Objective: Development of space flight techniques and technology. Payload: Geodetic satellite.	817 788 111.4 90.21**	Still in orbit.
Apr. 6 EARLY BIRD I 28A Thrust-Augmented Delta	Total weight: 87 lbs. Objective: Launch a communications satellite into synchronous orbit and cooperate in its operation as a commercial communications relay point. Payload: 28.4" x 23.25" cylindrical satellite, with 2 traveling wave tube transmitters with capacity of 240 duplex voice and TV channels, 2 VHF transmitters and associated telemetry equipment; 6 antennas; 6,000 n-on-p solar cells and 2 nickel-cadmium batteries; apogee motor and jets and tankage for control system.	22,683 21,700 1,436.4 0.13	EARLY BIRD I was launched into excellent preliminary orbit, so that on April 9--5 days ahead of schedule--the Communications Satellite Corporation, owner of the satellite, was able to fire its apogee motor and insert it into synchronous orbit. Within a week of launch it began communications between Europe and North America and has successfully offered continuous voice, TV, and data transmission. Launched by NASA under contract to ComSatCorp, EARLY BIRD I applied technology developed in the SYNCOM program. Still in orbit.

Apr. 9 DEFENSE Probe Blue Scout Jr.	Total weight: Not stated. Objective: To measure space environment effects on biological samples. Payload: Biological equivalent ionization chamber, magnetic electron spectrometer and telemetry equipment.	Orbit not intended.	Climbed about 18,000 miles up, reentered over the South Atlantic Ocean. Telemetry received for 15 minutes only.
Apr. 14 JOURNEYMAN Probe Argo-D-8	Total weight: 130 lbs. Objective: To provide synoptic data in a vertical shot near OGO I. Payload: Energetic particle detection instruments and telemetry equipment.	Orbit not intended.	Climbed 1,300 miles, but nose cone failed to separate so no radiation data returned, then fell about 1,200 miles away.
Apr. 28 DEFENSE 31A Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	171 95 88.1 95.00**	Decayed May 3, 1965.
Apr. 28 DEFENSE 31B Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	348 303 95.0 95.20**	Still in orbit.
Apr. 29 BEACON EXPLORER XXVII 32A Scout	Total weight: 132 lbs. Objective: Map irregularities in the Earth's gravitational field; continue collection of global electron counts for cross sections of the ionosphere; continue experiments with laser for tracking, geodetic, and communications purposes. Payload: 18" x 12" octagonal satellite, with 4 solar panels extending like windmill blades; 4 radio transmitters, 4 antennas; magnetometer; nickel-cadmium batteries; 360 1-in. glass-prism reflectors and laser signal detector; 2 bar magnets.	816 577 107.8 41.16	EXPLORER XXVII was successfully launched, 2nd in series of 5 satellites in geodetic research. Its results supplement those from EXPLORER XXII (making same measurements at 80° inclination). Electron-count experiment involves 86 ground stations in 36 countries, largest international effort to date. Still in orbit.

Apr. 29 DEFENSE 33A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	290 112 90.9 85.00	Decayed May 26, 1965. A part of the payload separated, was designated 33B, and it decayed June 8, 1965.
May 6 DEFENSE 34A Titan IIIA	Total weight: 7,000 lbs. Objective: Development of space flight techniques and technology. Payload: Not stated.	2,319 1,725 157.0 32.07	Still in orbit.
May 6 LES II 34B Titan IIIA	Total weight: 82 lbs. Objective: Development of space flight techniques and technology. Payload: Experimental communications satellite.	9,364 1,753 315.3 31.35	Still in orbit.
May 6 LCS I 34C Titan IIIA	Total weight: 75 lbs. Objective: Development of space flight techniques and technology. Payload: Radar calibration sphere.	1,729 1,721 145.6 32.11	Still in orbit.
May 12 DEFENSE Probe Blue Scout Jr.	Total weight: 47 lbs. Objective: To measure pitch angle and magnetic field intensity to 3 Earth radii. Payload: Sensors, batteries, and telemetry equipment.	Orbit not intended.	Climbed 8,536 miles on a flight of 3 hours 50 minutes before falling in the Indian Ocean. Successful in returning useful data.
May 18 DEFENSE 37A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	191 123 98.6 75.00	Decayed June 15, 1965.

May 19 APOLLO BP-22 System Test Little Joe II	Total weight: 28,000 lbs. Objective: Test launch escape system stabilization at maximum atmospheric altitude; test flight stability of launch escape system when heat shield is in forward position. Payload: 12'10" (dia. at base) x 11'2" conical boilerplate APOLLO command module, attached to 12'10" (dia.) x 13'2" boilerplate service module; 33'-long launch escape system; telemetry system; 3 motion picture cameras; 2 tape recorders; 5 zinc batteries; 2 drogue parachutes, 3 pilot parachutes, and 3 main parachutes.	Orbit not intended.	Little Joe II launch vehicle began to roll shortly after launch, was destroyed by centrifugal force at 14,000 ft. (of 112,000-ft. planned flight). Launch escape system functioned automatically, pulled APOLLO command module free at 19,000 ft.; it landed safely 3 mi. from launch site (of 110 mi. planned). Did not achieve primary objective of test at maximum altitude; did test flight stability with heat shield forward and as bonus did test escape system in emergency conditions.
May 20 DEFENSE 38A Thor FW4S	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	597 345 100.0 98.62**	
May 22 FIRE II Reentry Test Atlas Antares	Total weight: 200 lbs. (reentry package). Objective: Gather more data on highest reentry heating ranges for speeds comparable to reentry speeds from a lunar flight. Payload: 26" dia. cone 21" long, the blunt end consisting of 3 calorimeters interleaved with heat protection layers; 3 radiometers; 258 thermocouples; data recorders; 2 transmitters; attitude sensing system.	Orbit not intended.	FIRE II was a complete success, returning all necessary information to confirm the design of the APOLLO heat shield, and ended the FIRE series. The payload rose 500 mi. in a ballistic trajectory, was fired back into the atmosphere by X259 motor, hit 25,400 mph reentry speed, landed 5,130 mi. downrange after 32 min. flight.

May 25 PEGASUS II 39A Saturn I (SA-8)	Total weight: 23,100 lbs. (including 3,200 lbs. PEGASUS, 19,900-lb. S-IV 2nd stage with associated equipment). Objective: Study distribution, size, and velocity of meteoroids in near-Earth orbit; continue development of Saturn I launch vehicle. Payload: 96' (when unfolded in orbit) x 14' unfolding wings, composed of electrically charged panels sensitive to meteoroid hits, with center section containing motor for unfolding wings, telemetry, solar cells, batteries; all this affixed to 41-1/2' long S-IV 2nd stage of the Saturn launch vehicle.	458 313 97.2 31.73	Boilerplate APOLLO separated on schedule, PEGASUS II deployed its wings; by September 1965 PEGASUS II had recorded hits penetrating its 1.5-mil, 8-mil, and 16-mil-thickness panels at the respective rates of 58, 5.1, and 1.45 per sq. meter per year. SA-8 vehicle performed excellently, the 9th successful Saturn I flight in 9 attempts. Still in orbit.
May 25 APOLLO BP-26 39B Saturn I (SA-8)	Total weight: 9,700 lbs. Objective: To test separation techniques; to provide ballast; to measure total vehicle dynamics; and to provide a shroud for PEGASUS. Payload: Boilerplate APOLLO.	459 314 97.2 31.74	Still in orbit.
May 27 DEFENSE 41A Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	164 94 88.6 95.77**	Decayed June 1, 1965.

May 29 IMP EXPLORER XXVIII 42A Thor Delta	Total weight: 130 lbs. Objective: In very eccentric orbit, study magnetosphere, cosmic radiation, and solar wind. Payload: 28" (dia.) x 8 " octagonal spacecraft, with 6' boom deploying rubidium-vapor magnetometer, 2 7' booms deploying flux-gate magnetometers; 4 cosmic ray detectors; 3 solar-wind analyzers; 4 solar paddles mounting 6, 144 n-on-p solar cells; 13 silver-cadmium batteries; transmitter.	163,831 121 8,558.1 33.86	A slightly long burn of the booster engines put EXPLORER XXVIII in even more elliptical orbit (164,000-120 mi.) than planned (130,000-120 mi.). This was 3rd in IMP series (others were EXPLORERS XVIII and XXI). Still in orbit.
Jun. 3 GEMINI IV 43A Titan II	Total weight: 7,879 lbs. (includes reentry and adapter modules). Objective: Demonstrate performance of spacecraft and crew in spaceflight exceeding 4 days' duration. Payload: 18'5" x 10' 2-module bell-shaped spacecraft, containing 2 astronauts; guidance and control equipment; 3 cameras; 1 HF and 1 UHF transceiver, high and low frequency telemetry transmitters, tracking and recovery communications; batteries; environmental control system; reentry and recovery systems.	175 100 88.9 32.50	GEMINI IV completed the planned 62 revolutions (97 hrs. 59 min.), longest U.S. manned spaceflight to date. Astronauts James A. McDivitt and Edward H. White tried to rendezvous with their Titan booster on 1st orbit, but gave up because it was consuming too much of their maneuver fuel. On the 3rd orbit White made 1st U.S. walk in space, world's 1st extra-vehicular activity in which man had control over his movements; planned EVA of 10 min. lasted 22 min. GEMINI IV landed June 7, 1965 in the Atlantic 48 mi. short; astronauts were picked up by helicopter.

Jun. 3 RENDEZVOUS STAGE 43B Titan II	Total weight: 5,200 lbs. Objective: To serve as a rendezvous target as well as to lift GEMINI to orbit. Payload: Signal beacon.	175 100 88.9 32.50	Decayed June 5, 1965.
Jun. 9 DEFENSE Probe Blue Scout Jr.	Total weight: 31 lbs. Objective: To measure the effects of space radiation on human tissue equivalents. Payload: Tissue equivalent ion chamber, magnetic electron spectrometer, batteries, telemetry equipment.	Orbit not intended.	Climbed 10,897 miles up, and after a flight of 4 hours, 32 minutes, fell in the Indian Ocean. Successful in returning useful data.
Jun. 9 DEFENSE 45A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	206 109 89.7 75.07	Decayed June 22, 1965
Jun. 18 DEFENSE 47A Titan IIIC	Total weight: 29,300 lbs. gross, including a dummy payload of 21,400 lbs., of which 21,000 lbs. was lead ballast. Objective: Development of space flight techniques and technology. Payload: Lead ballast.	118 104 88.1 32.14	Decayed June 29, 1965. The ballast was separated from the transtage after six hours of flight.
Jun. 24 DEFENSE 48A Thor Able Star	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	704 640 106.9 90.0	Still in orbit.
Jun. 25 DEFENSE 50A Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	315 309 94.7 107.65**	Still in orbit.

Jun. 25 DEFENSE 50B Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	158 93 88.5 107.60**	Decayed June 30, 1965.
Jun. 29 APOLLO BP23-A System Test Escape Rocket	Total weight: 11,000 lbs. Objective: Pad abort test. Payload: Boilerplate APOLLO command capsule.	Orbit not intended.	The escape rocket boosted the command module about 5,000 feet, from where it parachuted to a safe landing.
Jun. 30 JOURNEYMAN Probe Argo D-8	Total weight: 137 lbs. Objective: To conduct a radio astronomy experiment on intensity of signals from outside the solar system. Payload: Unfurled antenna system of 70-foot spread, radio receivers at 750, 1125 and 2000 kc, batteries, and transmitters.	Orbit not intended.	Climbed 1,060 miles and fell 1,700 miles away after a 25-minute flight. Met flight objectives.
Jul. 2 TIROS X 51A Thrust-Augmented Delta	Total weight: 290 lbs. Objective: Continue development of a meteorological satellite system; provide continuity in weather observation; provide maximum coverage of hurricane season. Payload: 22" x 42" cylindrical 18-sided polygon, containing 2 TV cameras with 104° lens, photo storage; transmission system; magnetic attitude control system; 9,100 p-on-n solar cells; 63 nickel-cadmium batteries.	519 462 100.7 98.63**	TIROS X was doglegged into near-polar orbit; was 1st Weather Bureau-funded satellite; photo from TIROS X was 1st identification of Hurricane Betsy. Still in orbit.
Jul. 17 DEFENSE 55A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	318 292 94.4 70.17	Still in orbit.

Jul. 19 DEFENSE 57A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	275 112 90.7 85.05	Decayed August 18, 1965.
Jul. 20 VELA HOTEL V 58A Atlas Agena D	Total weight: 524 lbs. (spacecraft of 334 lbs. plus kick motor). Objective: To develop techniques for monitoring nuclear explosions detectable from space. Payload: 6 X-ray, 6 gamma ray, 1 neutron, and 2 "Z" particle detectors; 1 X-ray analyzer; 1 electron-proton spectrometer; 2 Geiger-Mueller tubes; 1 magnetometer; extreme ultraviolet detectors; solar cells, batteries, telemetry equipment.	59,644 54,913 5,148.2 35.26	Still in orbit.
Jul. 20 VELA HOTEL VI 58B Atlas Agena D	Total weight: 524 lbs. (spacecraft of 334 lbs. plus kick motor). Objective: To develop techniques for monitoring nuclear explosions detectable from space. Payload: 6 X-ray, 6 gamma ray, 1 neutron, and 2 "Z" particle detectors; 1 X-ray analyzer; 1 electron-proton spectrometer; 2 Geiger-Mueller tubes; 1 magnetometer; extreme ultraviolet detectors; solar cells, batteries, telemetry equipment.	75,483 63,138 6,726.1 34.98	Still in orbit.

Jul. 20 ORS III-1 58C Atlas Agena D	Total weight: 12 lbs. Objective: To monitor background radiation in the Van Allen belts. Payload: Octahedron research satellite, with detectors, solar cells and telemetry equipment.	69,870 95 2,610.5 34.39	Still in orbit.
Jul. 30 PEGASUS III 60A Saturn I (SA-10)	Total weight: 23,700 lbs. (including 3,200 lb. PEGASUS, 19,900-lb. S-IV 2nd stage and associated equipment, and 600 lbs. of propellant). Objective: Continue study of distribution, size, and velocity of meteoroids in near-Earth orbit; continue development of Saturn I launch vehicle. Payload: 96' (when unfolded in orbit) 14' unfolding wings, composed of electrically charged removable panels sensitive to meteoroid hits, with center section containing motor for unfolding wings, telemetry, solar cells, batteries; all this affixed to 41-1/2'-long S-IV 2nd stage of the Saturn launch vehicle.	332 319 95.2 28.87	PEGASUS III was orbited with removable meteoroid detection panels, for possible retrieval from space by a future astronaut flight; results to October 8 had hits recorded on its 1.5-mil, 8-mil, and 16-mil-thickness panels at the respective rates of 58, 5.1, and 1.45 per sq. meter per year. This launch completed the PEGASUS series, with 3 successes out of 3 attempts. SA-10 vehicle performed excellently, completing the launch vehicle development program for Saturn I with a perfect record of 10 successes out of 10 attempts. Still in orbit.
Jul. 30 APOLLO BP-9 60B Saturn I (SA-10)	Total weight: 10,100 lbs. Objective: To test separation techniques; to provide ballast; to measure total vehicle dynamics; and to provide a shroud for PEGASUS. Payload: Boilerplate APOLLO.	332 322 95.2 28.86	Still in orbit.

Aug. 3 DEFENSE 62A Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	171 94 88.7 107.40**	Decayed August 7, 1965.
Aug. 3 DEFENSE 62B Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	316 312 94.7 107.3**	Still in orbit.
Aug. 10 SECOR V 63B Scout FW4S	Total weight: 44 lbs. Objective: Flight-qualify and demonstrate major new components of the Scout launch vehicle; orbit a SECOR satellite. Payload: Spherical satellite, containing transponder, solar cells and batteries, telemeter, antennas, for geodetic purposes.	1,505 703 122.2 69.22	Scout (SEV-A) performed excellently in its test flight, including the new motors in 2nd and 4th stages and new spacecraft separation system. The U.S. Army's geodetic satellite SECOR V operated satisfactorily. Still in orbit.
Aug. 11 SURVEYOR 64A Atlas Centaur (AC-6)	Total weight: 6,230 lbs. (including 2,084 lb. SURVEYOR). Objective: In full-scale simulation, determine capability of the Atlas-Centaur vehicle to launch a SURVEYOR spacecraft on a lunar transfer trajectory; test new system components on launch vehicle. Payload: SURVEYOR Dynamic Model (SD-2), consisting of SURVEYOR spaceframe, simulated retromotor assembly, S-band transponder, spacecraft separation assembly.	510,861 104 31 days 28.56	Simulated SURVEYOR spacecraft was launched into a precise, deliberately offset lunar transfer orbit; guidance was so accurate that an actual spacecraft would have hit the Moon without need of midcourse correction. First flight with a Centaur stage of the uprated Atlas engines (total of 389,000 lbs. thrust); 4th success in 6 Atlas-Centaur flights. Still in orbit.

Aug. 13 SURCAL 65B Thor Able Star	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Calibration satellite for Spasur System, Long Rod of 200 feet, intended to separate from carrier rocket and then deploy.	719 675 107.8 90.02**	Still in orbit. The Long Rod failed to separate from the final stage of the Thor Able Star carrier rocket, and to expand to the length intended. (Some observers think 65J is the Long Rod, but that is assessed as only a piece of wire debris.)
Aug. 13 SURCAL 65C Thor Able Star	Total weight: 9 lbs. Objective: Development of space flight techniques and technology. Payload: Calibration satellite for Spasur System, Dodecapod shape.	733 679 108.1 90.02**	Still in orbit.
Aug. 13 SURCAL 65E Thor Able Star	Total weight: 20 lbs. Objective: Development of space flight techniques and technology. Payload: Calibration satellite for SPASUR System, Black Sphere.	738 680 108.2 90.00	Still in orbit.
Aug. 13 DEFENSE 65F Thor Able Star	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	740 676 108.1 90.02**	Still in orbit.
Aug. 13 SURCAL 65H Thor Able Star	Total weight: 5 lbs. Objective: Development of space flight techniques and technology. Payload: Calibration satellite for Spasur System, White Sphere.	737 678 108.1 90.04**	Still in orbit.
Aug. 13 SURCAL 65L Thor Able Star	Total weight: 13 lbs. Objective: Development of space flight techniques and technology. Payload: Calibration satellite for Spasur System, with transponder.	741 674 108.1 90.03**	Still in orbit.

Aug. 17 DEFENSE 67A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	262 131 90.9 70.01	Decayed October 11, 1965.
Aug. 21 GEMINI V 68A Titan II	Total weight: 7,947 lbs. (includes re-entry and adapter modules). Objective: Demonstrate performance of spacecraft and crew in 8-day spaceflight; evaluate performance of rendezvous guidance and navigation system using the radar evaluation pod. Payload: 18'5" x 10' 2-module bell-shaped spacecraft, containing 2 astronauts; guidance and control equipment; rendezvous radar and navigation system; cameras, 1 HF and 1 UHF transceiver, high and low frequency telemetry transmitters, tracking and recovery communications; fuel cell; environmental control system; recovery and reentry systems.	217 101 89.6 32.60 Later orbits: 193 125 89.6 32.60	GEMINI V set new world record for longest manned space flight (190 hrs. 56 min., 120 revolutions), confirmed that astronauts were physically able to withstand lunar spaceflight, and, in spite of minor problems, confirmed operation of the fuel cell and rendezvous radar. Astronauts L. Gordon Cooper, Jr., and Charles Conrad, Jr., performed 16 of 17 planned experiments; human error by ground crew caused GEMINI V to land 90 mi. short on August 29, 1965, and helicopter picked up crew.
Aug. 21 REP 68C Titan II	Total weight: 76 lbs. Objective: To serve as a rendezvous target for GEMINI. Payload: Radar transponder, flashing xenon lights.	217 101 89.6 32.60	Decayed August 27, 1965.
Sep. 10 DEFENSE 72A Thor FW4S	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	655 401 101.9 98.65**	Still in orbit.

Sep. 22 DEFENSE 74A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	222 109 89.9 80.05	Decayed October 11, 1965
Sep. 30 DEFENSE 76A Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	168 88 88.6 95.55**	Decayed October 5, 1965.
Oct. 5 AEROSPACE RESEARCH SATELLITE 78A Atlas	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Instruments to map and monitor energetic particles, mass spectrometers, and detectors imbedded in radiation shield, instruments measuring dose rates in tissue-equivalent medium, and telemetry equipment.	2,141 255 125.7 144.3**	Still in orbit. Carried as a pick-a-back on a regular missile test, it entered the first highly retrograde orbit. Successfully returned data.
Oct. 5 DEFENSE 79A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	195 125 89.6 75.02	Decayed October 29, 1965.
Oct. 14 OGO II 81A Thor Agena D	Total weight: 1,150 lbs. Objective: Take geophysical measurements of the near-Earth environment during a period of low solar activity in study of correlative aspects of the relationship between the Sun and the Earth environment. Payload: 67" x 32" x 31" rectangular parallelepiped spacecraft, containing many of the experiments and subsystems such as telemetry, attitude control, temperature control, nickel-cadmium batteries; deployed from the spacecraft	936 257 104.3 87.36	OGO II was launched into higher orbit than planned because of failure of primary launch vehicle guidance; 19 of the 20 experiments operated and returned data, but trouble with the horizon scanners depleted the stabilization gas supply, which in turn caused electrical supply depletion; OGO II ceased transmitting October 24, 1965.

	are 2 22' booms and 4 4' booms on the ends of which experiments are mounted; extended from the spacecraft are 2 large rotatable solar paddles faced with 33,000 solar cells; 20 experiments.		
Oct. 15 DEFENSE LCS II OV2-1 82A Titan IIIC	Total weight: Not stated, but OV2-1 is 375 lbs. Objective: Development of space flight techniques and technology. Payload: First part, not stated. LCS II, a radar calibration sphere. OV2-1 has 3 energetic particle detectors, 5 spectrometers, Faraday cup, Cerenkov counter, 2 flux-gate magnetometers, VLF receiver, 2 plasma probes, proton detector, tissue-equivalent ion chamber, 3 proton spectrometers, low energy magnetic electron spectrometer, DE/DX telescope.	615 324 99.9 31.85	Still in orbit. Statistically counts as three payloads. However, about the time of the second burn of the transtage, the total assemblage exploded into hundreds of fragments, and were therefore not useful beyond the earlier steps of launch vehicle testing, the primary mission of the flight.
Oct. 28 DEFENSE 86A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	268 107 90.6 74.97	Decayed November 17, 1965.
Nov. 6 GEOS EXPLORER XXIX 89A Improved Thrust-Augmented Delta	Total weight: 385 lbs. Objective: Provide geodetic measurements that will relate continental and local geodetic datums into a one-world datum related to the Earth's common center of mass; map the structure of the Earth's gravitational field. Payload: 48" (dia.) octagon topped by octagonal cone, for a total spacecraft height of 32"; below the spacecraft protrudes a 24"-dia. hemisphere antenna; inside the spacecraft are a clock, memory computer system, telemetry, 3 power systems, and geodetic instruments; the (cont'd)	1,411 691 120.3 59.36	EXPLORER XXIX was launched into orbit with higher apogee than planned because 2nd stage did not cut off on ground command. All experiments functioned. First use of Improved Thrust-Augmented Delta launch vehicle.

	face of the satellite is surfaced with 4,992 solar cells, 4 flashing-light beacons, 4 silvered quartz corner reflectors for laser experiments; 60' boom deploys for gravity-gradient stabilization; antennas.		
Nov. 8 DEFENSE 90A Atlas Agena	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	174 88 88.7 93.90**	Decayed November 11, 1965.
Nov. 8 DEFENSE 90B Atlas Agena	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	176 96 88.9 93.90**	Decayed November 9, 1965.
Nov. 19 SOLRAD EXPLORER XXX 93A Scout	Total weight: 125 lbs. Objective: Monitor the Sun's X-ray emission; measure the time history of X-ray intensity in relation to solar flares; provide real-time solar monitoring data to participants in IQSY. Payload: 2 24"-dia. hemispheres separated by 3-1/2" band in which are mounted 12 photometers and 4 telemetry antennas; data storage system; 2 transmitters, 2 receivers; solar cells, nickel-cadmium batteries.	549 439 100.8 59.70	EXPLORER XXX, 9th SOLRAD satellite developed by the Navy Research Laboratory, was launched by NASA for the U.S. Navy as part of U.S. participation in IQSY. All experiments functioned well. Still in orbit.
Nov. 29 ALOUETTE II 98A Thor Agena B	Total weight: 323 lbs. Objective: As part of ISIS-X program, simultaneously with a companion satellite, measure characteristics of the ionosphere, both as a topside sounder and in the vicinity of the spacecraft. Payload: 42" (dia.) x 34" near-oval spacecraft, containing 5 experiments, transmitter, receiver, nickel-cadmium	1,852 313 121.4 79.82	ALOUETTE II, Canadian-built satellite, was launched with EXPLORER XXXI by a single Thor Agena booster as part of the joint U.S.-Canadian ionospheric research program. Satellite performance was excellent. Still in orbit.

	batteries; surface covered with 6,480 n-on-p solar cells; extending from the satellite are 2 dipole antennas, one 75', the other 240'; 5 whip antennas.		
Nov. 29 DIRECT MEASUREMENT EXPLORER XXXI 98B Thor Agena B	Total weight: 218 lbs. Objective: As part of ISIS-X program, simultaneously with a companion satellite measure density and temperature of ions and electrons, composition of ions, and corpuscular radiation. Payload: 30" (dia.) x 25" octagonal spacecraft with spherical ion mass spectrometer protruding 21" above it; inside are most of 8 experiments, transmitter, telemetry, battery; outside are solar cells, antenna.	1,846 313 121.3 79.82	EXPLORER XXXI, U.S. companion satellite to Canadian ALOUETTE II, was launched with the other satellite by a single Thor Agena booster as part of the joint U.S.-Canadian ionospheric research program. This was the 1st of 4 projected launches. EXPLORER XXXI was performing well. Still in orbit.
Dec. 4 GEMINI VII 100A Titan II	Total weight: 8,076 lbs. (includes reentry and adapter modules). Objective: Demonstrate performance of GEMINI spacecraft and crew in 14-day flight; serve as target vehicle for rendezvous attempt. Payload: 18'5" x 10' 2-module bell-shaped spacecraft, containing 2 astronauts; guidance and control equipment; rendezvous radar; cameras; 1 HF and 1 UHF transceiver; high and low frequency telemetry transmitters, tracking and recovery communications; fuel cell; environmental control system; recovery and reentry systems.	204 100 89.39 28.89 Target orbit: 188 183 90.2 28.89	GEMINI VII broke GEMINI V's world record for longest manned spaceflight (330 hrs. 35 min., 206 revolutions); returned Astronauts Frank Borman and James A. Lovell in excellent condition, confirming human adaptability to conditions of spaceflight; participated as target vehicle for GEMINI VI's successful space rendezvous; collected valuable data on all 20 planned experiments; landed December 18, 1965, 9 mi. from U.S.S. Wasp; astronauts were picked up by helicopter.

Dec. 6 FR-1 (FRIA) 101A Scout	Total weight: 135 lbs. Objective: Study the very-low frequency wave field in the magnetosphere and irregularities in distribution of ionization in the magnetosphere. Payload: 27" (dia. across corners) x 52" spacecraft consisting of octagonal central section faced with 2 octagonal prisms covered with solar cells; 19" boom with electron-density probe deploys below spacecraft; above the spacecraft extends magnetic-field antenna; from the sides extend 4 6-1/2' dipole antennas for electrical field measurement; 4 telemetry antennas; magnetometer; 2 transmitters; 2 nickel-cadmium batteries.	469 464 99.9 75.87	FR-1 was launched for France by NASA under joint U.S.-France space research program. Experiments with FR-1 would be conducted at both French and U.S. ground stations using radio equipment furnished by France. Spacecraft was functioning well. Still in orbit.
Dec. 9 DEFENSE 102A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	260 112 90.5 80.02	Decayed December 26, 1965.
Dec. 15 GEMINI VI 104A Titan II	Total weight: 7,817 lbs. (includes reentry and adapter modules). Objective: Perform space rendezvous to within a few feet of target vehicle, GEMINI VII. Payload: 18'5" x 10' 2-module bell-shaped spacecraft, containing 2 astronauts; guidance and control equipment; rendezvous radar and navigation equipment; cameras; 1 HF and 1 UHF transceiver, high and low frequency telemetry transmitters, tracking and recovery communications; batteries; environmental control system; recovery and reentry systems.	161 100 88.7 28.97 Rendezvous orbit: 188 183 90.2 28.89	GEMINI VI performed world's first piloted rendezvous in space; beginning in their 2nd revolution, Astronauts Walter M. Shirra, Jr., and Thomas P. Stafford started a series of spacecraft maneuvers to catch up with GEMINI VII, with 5 maneuvers producing circular orbit (172/171) after 3 hrs. 47 min. of flight; radar lockon with GEMINI VII was confirmed at 4 hrs. 16 min. at a distance of 235 mi.; 4 more

			maneuvers effected rendezvous; for 5 hrs. 16 min. rendezvous was maintained, the spacecraft coming as close as 1 ft. GEMINI VI reentered and landed December 16, 1965, after 25 hrs. 52 min. (16 revolutions), impacting in the Atlantic 7.6 mi. from aiming point; astronauts were hoisted aboard U.S.S. <u>Wasp</u> in their spacecraft.
Dec. 16 PIONEER VI 105A Improved Thrust-Augmented Delta	Total weight: 140 lbs. Objective: Obtain scientific data on interplanetary phenomena at points closer to the Sun than is the Earth's orbit. Payload: 37" (dia.) x 35" cylindrical spacecraft, with a boom protruding from the top containing communications antennas; the sides covered with solar cells except for a narrow band in which are placed the experiments and 3 booms, 2 for orientation jets and 1 for the magnetometer; data storage; transmitter; batteries; 6 experiments.	0.98au* 0.81au 311 days 0.20	PIONEER VI was successfully placed in heliocentric orbit; 1st of projected 4 PIONEER interplanetary spacecraft studying the solar wind, solar physics, magnetic fields of the Sun, and interactions of high-energy particles and magnetic fields. Spacecraft was functioning well.
Dec. 21 OV2-3 108A Titan IIIC	Total weight: Not stated, but OV2-3 portion is 427 lbs. Objective: Development of space flight techniques and technology. Payload: Instruments to measure solar and geomagnetic activity, cosmic rays, trapped particle fluxes, magnetometers, spectrometers, and telemetry equipment.	20,857 110 589.7 26.38	In the 3rd test for vehicle development of the Titan IIIC, it was intended to fly the transtage to a circular, near-synchronous orbit at 20,960 miles, when it would release 4 pick-a-back payloads. The vehicle attained a first orbit, (cont'd)

			circular at 105 miles. 75 minutes after launch, the transtage refired to the eccentric orbit listed in the previous column. It was to coast for about 5 hours, then fire again. A defective valve brought a tumbling mode, so the transtage did not restart. OV2-3 remained attached. Still in orbit.
Dec. 21 LES IV 108B Titan IIIC	Total weight: 115 lbs. Objective: Development of space flight techniques and technology. Payload: Experimental Communications Satellite with solid state transponder in 8,000 mc region.	20,844 124 589.6 26.60	Telemetry indicated a successful release. After a few days of doubt, power levels built up to permit successful use. Still in orbit.
Dec. 21 OSCAR IV 108C Titan IIIC	Total weight: 41 lbs. Objective: To provide experimental communications for radio amateurs in all countries. Payload: Amateur Radio Communications Satellite with transponder, power supply.	Not available.	Telemetry indicated a successful release. It is functioning well, as intended. Because of its extreme orbit, these parameters have not yet been determined precisely. Still in orbit.
Dec. 21 LES III 108 Titan IIIC	Total weight: 35 lbs. Objective: Development of space flight techniques and technology. Payload: Experimental Communications Satellite with signal generator in 300 mc UHF band.	Not available.	Telemetry indicated a successful release, and its signals have been received. Until its orbit can be determined, it has not been assigned a letter designator. Still in orbit.

Dec. 22 DEFENSE 109A Scout	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	674 563 105.0	Still in orbit.
Dec. 24 DEFENSE 110A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	268 112 90.7 80.01	Still in orbit.

NOTES: Successful launches are judged solely by the criterion of whether orbit of Earth or escape from Earth was achieved when so intended. Additionally, the table includes listings of important probes and vehicle tests not intended to orbit, but in these cases, no criterion of success has been applied; some achieved their purposes, others did not. Seven additional Earth-orbital launchings with eight payloads not in this table failed to achieve orbit.

Launch date is based on Greenwich mean time.

Name is the payload identification.

Designation is the international COSPAR astronautical number of orbital objects.

Vehicle is the launch craft type.

Total weight refers to the orbital weight of the object containing the payload; it does not include the weight of any separate miscellaneous burned-out rocket casings, protective coverings, etc.

Objective and Payload are self-explanatory.

Orbital elements are those filed with the United Nations as available; otherwise they are taken from the NASA Goddard Satellite Situation Report or other official public releases.

Apogee and Perigee refer to the greatest and least distances respectively from the Earth of geocentric orbiting objects. In the case of data marked with an asterisk(*), the data refer to Aphelion and Perihelion, the farthest and closest distance between objects in heliocentric orbit and the Sun. These latter instead of being measured in statute miles are measured in astronomical units. (The mean distance between Earth and Sun is called 1 au.)

Period refers to the time in minutes (unless otherwise marked) required to complete one Earth orbit. (In the case of heliocentric orbits the period is measured in days.)

Inclination refers to the tilt of Earth orbits in relation to the Equator, measured in degrees of latitude at the points of the orbit farthest away from the Equator. Inclinations in excess of 90 degrees carry double asterisks (**), indicating some amount of retrograde flight, i.e., somewhat westerly instead of the normal easterly. In the case of heliocentric flights, the inclination is measured in degrees of tilt to the Ecliptic (the plane of the Earth's orbit in relation to the Sun.)

Remarks are self-explanatory.

Appendix A-3 — NASC Staff

RADIOISOTOPE GENERATORS FOR SPACE APPLICATIONS

SNAP NO.	Power Electrical (watts)	Life (years)	Application	Fuel	Status
3	2.7	5	Navigation Satellite (Navy)	Plutonium-238	Units launched 6/61 & 11/61. June unit still powering transmitter signals. Converter on November unit shorted out 6/62.
9A	25	5	Navigation Satellite (Navy)	Plutonium-238	Units launched 9/63 & 12/63. Satisfactorily providing all power required by satellites. Third unit aborted April 1964.
11	25	1/3	Experimental Devices	Curium-242	Electrically-heated models scheduled for delivery to Jet Propulsion Lab. and Manned Space Center mid-1966.
17	30	3-5	Communications Satellites	Strontium-90	Two generator design and component test contracts (Phase I) terminated 11/64. (T/E modules continue under test.)
19	30	5	NIMBUS-B (NASA)	Plutonium-238	Electrically-heated generators on test at AEC and NASA contractor installations.
27	50	5	APOLLO Lunar Surface Experiment Packages (NASA)	Plutonium-238	Two Phase I design studies completed. Phase II begun 8/65.

EXECUTIVE OFFICE OF THE PRESIDENT
NATIONAL AERONAUTICS AND SPACE COUNCIL
WASHINGTON

December 31, 1965

LISTING OF MAJOR SPACE "FIRSTS" ACHIEVED BY THE U. S. AND THE U. S. S. R.

One of the indexes used to compare the space programs of the United States and the Soviet Union are the "firsts" achieved by each nation. Like all indexes which measure the quantity but not the quality of achievement, such compilation can be misleading. However, a compilation of "firsts" broken down into meaningful areas can help in judging emphasis and even relative progress if coupled with other evidence.

Regardless of whether a "first" gives either country a significant lead in a particular area of space technology, the fact of being first is not insignificant in the formation of public opinion. In fact, regardless of actual technological competence, the relative position of the U.S. and the U. S. S. R. in space is often judged by the "firsts" achieved by each.

A list of all of the "firsts" scored by each side would be long and meaningless. An effort has been made to select those actions or accomplishments which seemed to be of major importance. Moreover, because of the closed nature of some aspects of both nations' space programs, the list of "firsts" is even less complete.

In order to establish some measure of perspective, the list of "firsts" on the opposite page, is divided into major categories of space interest. Other breakdowns could have been employed. Most important to note is that this is not a comparison of space competence but rather is primarily a cataloging based upon the timing of events.

LISTING OF MAJOR SPACE "FIRSTS" ACHIEVED BY THE U.S. AND THE U.S.S.R.

	UNITED STATES			UNION OF SOVIET SOCIALIST REPUBLICS		
	Event	Satellite	Launch Date	Event	Satellite	Launch Date
SCIENCE	Discovery of Van Allen Radiation Belt	Explorer I	2/1/58	First orbiting geophysical laboratory	Sputnik III	5/15/58
	Discovery that the Earth is "pear shaped"	Vanguard I	3/17/58	First photos of the moon's far side	Luna III	9/12/59
	First orbiting solar observatory	OSO I	3/7/62	First comprehensive cosmic ray space station	Proton I	7/16/65
	First successful probe of Venus	Mariner II	8/27/62			
	First geodetic satellite	Anna IB	10/31/62			
	First close-up pictures of the lunar surface	Ranger VII	7/28/64			
	First satellite to communicate over 100 million miles	Mariner IV	11/28/64			
	First space pictures of Mars	Mariner IV	11/28/64			
	First comprehensive micrometeroid satellite	Pegasus I	2/16/65			
APPLICATIONS	First active communications satellite	Score	12/18/58			
	First TV pictures from space	Explorer VI	8/7/59			
	First weather satellite	Tiros I	4/1/60			
	First navigation satellite	Transit IB	4/13/60			
	First missile detection satellite	Midas II	5/24/60			
	First passive communications satellite	Echo I	8/12/60			
	First nuclear explosion detection satellite	Vela Hotel	10/17/63			
BIOASTRONAUTICS AND MANNED SPACE FLIGHT	First manned orbital maneuver	Gemini III	3/23/65	First biosatellite	Sputnik II	11/3/57
	First propulsion by "Space Gun" outside orbiting spacecraft	Gemini IV	6/3/65	First animals orbited and recovered	Sputnik-Cosmic II	8/19/60
	First effective and sustained rendezvous of two manned ships	Gemini VI and VII	12/4/65 12/15/65	First human orbited and recovered	Vostok I	4/12/61
				First approximate rendezvous of two manned ships	Vostok III & IV	8/13/62
				First multi-manned ship in orbit	Voskhod I	10/12/64
				First man to leave capsule in space	Voskhod II	3/18/65
SPACE FLIGHT AND PROPULSION	First orbiting of two spacecraft by same launch vehicle	Transit IIA & Greb I	6/22/60	First satellite	Sputnik I	10/4/57
	First recovered payload	Discoverer XIII	8/11/60	First escape payload	Luna I	1/2/57
	First air snatch recovery of payload	Discoverer XIV	8/19/62	First lunar impact	Luna II	9/12/59
	First synchronous satellite	Syncom II	7/26/62	First orbital launch platform	Sputnik V	2/12/61
	First to place two satellites in different orbits	Vela Hotel I & II	10/17/63	First flight-by Venus	Venus I	2/12/61
	First hydrogen-fueled rocket to orbit satellite	Centaur II	11/27/63	First flight -by Mars	Mars I	11/1/62
	First sub-orbital test of an ion engine	SERT I	7/20/64	First ion engine test in orbit	Voskhod I	10/12/64
				First plasma rocket tested in orbit	Zond II	11/30/64
AUXILIARY POWER SYSTEMS	First solar cells operating on spacecraft	Vanguard I	3/17/58			
	First spacecraft with isotope nuclear power	Transit IVA	6/29/61			
	First spacecraft powered exclusively by nuclear energy	Transit V	9/28/63			
	First nuclear reactor in orbit	Snapshot I	4/3/65			
	First space use of fuel cell	Gemini V	8/21/65			

December 31, 1965
NATIONAL AERONAUTICS AND SPACE COUNCIL STAFF

UNITED STATES STATES SPACE LAUNCH VEHICLES

Vehicle	Stages	Propellant	Thrust (in Thousands of pounds)	Max. Dia. (feet)	Height less Spacecraft (feet)	Payload (pounds) 300 NM orbit	Escape	First Launch
Scout	1. Algol (IIB)	Solid	88	3.3	72	265	--	1965 (60)*
	2. Castor II	Solid	63					
	3. Antares II	Solid	22					
	4. Altair II	Solid	5.8					
Thor Delta	1. Thor (DSV-3E-1)	LOX/RP	169	8	90	950	150	1966 (60)
	2. Delta (DSV-3)	IRFNA/UDMH	7.1					
	3. Altair II	Solid	5.8					
Thrust augmented Thor Delta	1. Thor (DSV-3E-1) plus three TX33-52	LOX/RP Solid	169 plus 54 each	11	90	1,200	210	1965 (60)
	2. Delta (DSV-3)	IRFNA/UDMH	7.1					
	3. Altair II	Solid	5.8					
Thor Agena	1. Thor (DM-21)	LOX/RP	170	8	76	1,600	--	1962 (59)
	2. Agena	IRFNA/UDMH	16					
Thrust augmented Thor Agena	1. Thor (DM-21) plus 3 TX 33-52	LOX/RP Solid	170 54 each	11	76	2,200		1963 (60)
	2. Agena	IRFNA/UDMH	16					
Atlas Agena	1. Atlas booster and sustainer	LOX/RP	388	10	91	5,900	950	1961 (60)
	2. Agena	IRFNA/UDMH	16					
Titan II (GLV)	1. Two LR-87	N_2O_4/Aerozine 50	430	10	90	8,500 **	--	1964
	2. LR-91	N_2O_4/Aerozine 50	100					
Titan IIIA	1. Two LR-87	N_2O_4/UDMH	430	10	110	5,000	--	1964
	2. LR-91	N_2O_4/UDMH	100					
	3. Transtage	N_2O_4/UDMH	16					

Titan IIIB Agena	1.	Two LR-87	N_2O_4/UDMH	430	10	112	7,700	1,700	1966
	2.	LR-91	N_2O_4/UDMH	100					
	3.	Agena	LOX/RP	16					
Titan IIIC	1.	Two 5-segment 120" diameter	Solid	2,400	10 x 30	110	23,000	5,000	1965
	2.	Two LR-87	N_2O_4/UDMH	430					
	3.	LR-91	N_2O_4/UDMH	100					
	4.	Transtage	N_2O_4/UDMH	16					
Atlas Centaur	1.	Atlas booster and sustainer	LOX/RP	388	10	112	8,500	2,300	1962
	2.	Centaur (Two RL-10)	LOX/LH	30					
Saturn I	1.	S-I (8 H-1)	LOX/RP	1,500	21.6	120	15,000	--	1st stage 1961 2nd stage Block II 1964
	2.	S-IV (6 RL-10)	LOX/LH	90					
Saturn I-B	1.	S-IB (8 H-1)	LOX/RP	1,600	21.6	142	32,000		1966
	2.	S-IVB (1 J-2)	LOX/LH	200					
Saturn V	1.	S-IC (5 F-1)	LOX/RP	7,500	33	281	250,000	95,000	1967
	2.	S-II (5 J-2)	LOX/LH	1,000					
	3.	S-IVB (1 J-2)	LOX/LH	200					

NOTES: Definitive data are difficult to compile. Payload capacity data vary according to the place and direction of launch as well as intended orbital altitude. Vehicles still under development may fall short of or exceed their projected capacities, both in payload and in engine thrust. First stage thrust shown is sea level value. Modifications of existing vehicles have already raised their performance, and future modifications may be expected in several cases. In general, these data apply to the latest versions now under development.
* The date of first launch applies to this latest modification with a date in parentheses for the earlier version.
** Approximate value for 105 NM circular orbit out of ETR.

Propellant abbreviations used are as follows: Liquid Oxygen and a modified Kerosene -- LOX/RP; Solid propellant combining in a single mixture both fuel and oxidizer -- Solid; Inhibited Red Fuming Nitric Acid and Unsymmetrical Dimethlhydrazine -- IRFNA/UDMH; Nitrogen Tetroxide and Aerozine 50 -- N_2O_4/Aerozine 50; Liquid Oxygen and Liquid Hydrogen -- LOX/LH.

Values marked -- are either zero or not pertinent for the vehicle.

SPACE ACTIVITIES OF THE UNITED STATES GOVERNMENT

Historical Summary and 1967 Budget Recommendations January 24, 1966

NEW OBLIGATIONAL AUTHORITY

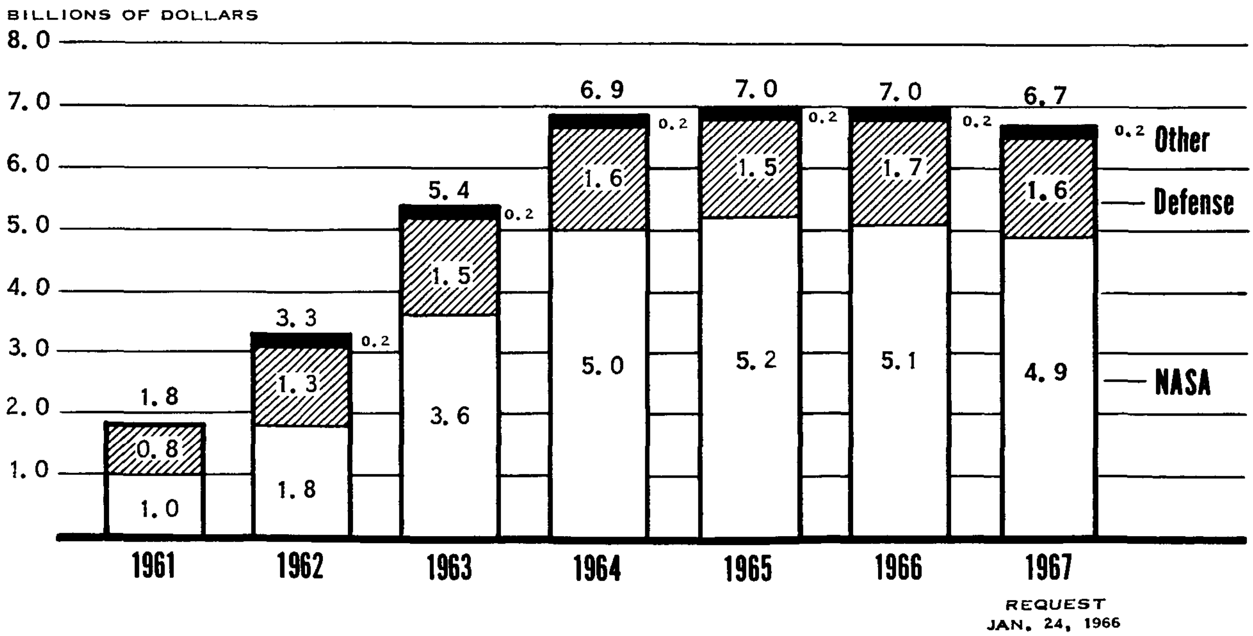
(In millions of dollars)

	NASA Total	NASA Space 1/	Dept. of Defense	AEC	Weather Bureau	NSF	Total Space
Historical							
1955	56.9	56.9	3.0	-	-	-	59.9
1956	72.7	72.7	30.3	7.0	-	7.3	117.3
1957	78.2	78.2	71.0	21.3	-	8.4	178.9
1958	117.3	117.3	205.6	21.3	-	3.3	347.5
1959	305.4	235.4	489.5	34.3	-	-	759.2
1960	523.6	461.5	560.9	43.3	-	.1	1,065.8
1961	964.0	926.0	813.9	67.7	-	.6	1,808.2
1962	1,824.9	1,796.8	1,298.2	147.8	50.7	1.3	3,294.8
1963	3,673.0	3,626.0	1,549.9	213.9	43.2	1.5	5,434.5
1964	5,099.7	5,046.3	1,599.3	210.0	2.8	3.0	6,861.4
1965	5,249.7	5,167.6	1,579.4	228.6	12.2	3.2	6,991.0
1967 Budget							
1966	5,174.9	5,087.9	1,693.5	195.6	27.3	3.6	7,007.9
1967	5,012.0	4,908.3	1,620.7	173.5	35.8	2.9	6,741.2

1/ Excludes amounts for aircraft technology in 1959 and succeeding years. Amounts for NASA-NACA aircraft and space activities not separately identifiable prior to 1959.

Source: Bureau of the Budget

U.S. SPACE BUDGET - NEW OBLIGATIONAL AUTHORITY



NASC STAFF

SPACE ACTIVITIES OF THE UNITED STATES GOVERNMENT

Historical Summary and 1967 Budget Recommendations January 24, 1966

EXPENDITURES

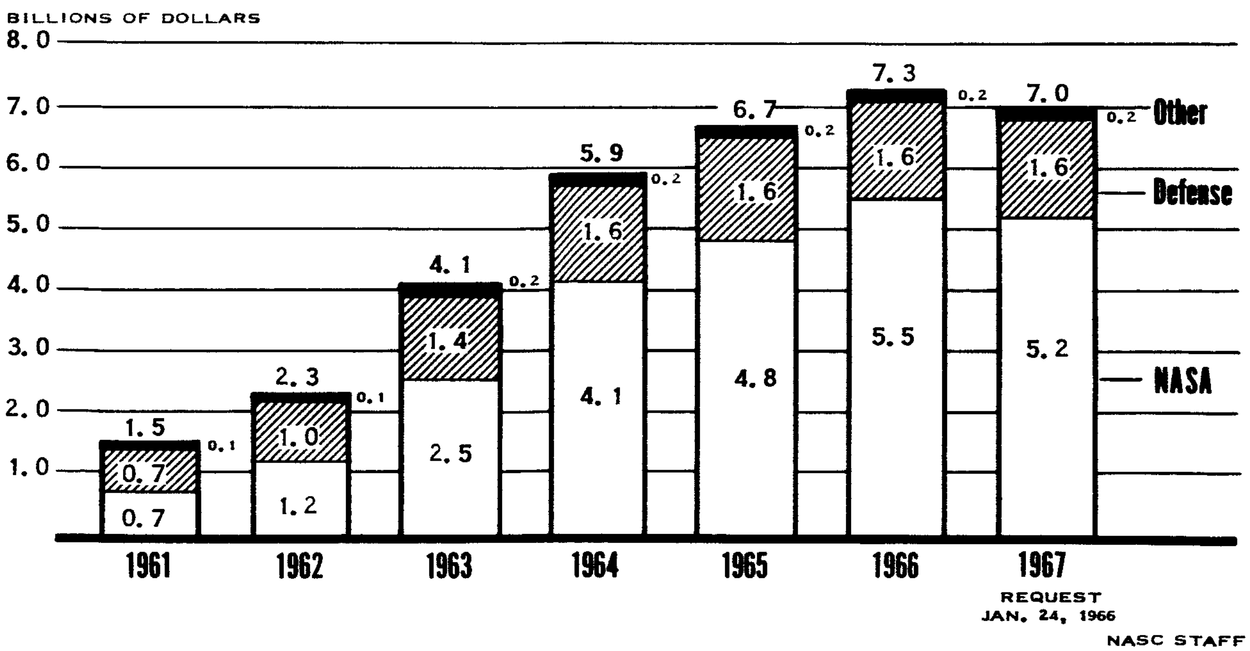
(In millions of dollars)

	NASA Total	NASA Space 1/	Dept. of Defense	AEC	Weather Bureau	NSF	Total Space
Historical							
1955	73.8	73.8	1.5	-	-	-	75.3
1956	71.1	71.1	16.5	6.3	-	6.2	100.1
1957	76.1	76.1	47.5	19.2	-	7.3	150.1
1958	89.2	89.2	135.5	20.2	-	4.0	248.9
1959	145.6	58.8	341.0	32.6	-	1.5	433.9
1960	401.0	329.2	518.1	41.1	-	-	888.4
1961	744.3	693.6	710.0	64.3	-	-	1,467.9
1962	1,257.0	1,225.9	1,028.8	130.0	1.0	.9	2,386.6
1963	2,552.3	2,516.8	1,367.5	181.0	12.2	1.1	4,078.6
1964	4,171.0	4,131.3	1,563.5	220.1	12.3	2.6	5,929.8
1965	5,092.9	5,035.0	1,591.8	232.2	24.1	3.0	6,886.1
1967 Budget							
1966	5,600.0	5,521.0	1,640.0	201.0	19.2	3.5	7,384.1
1967	5,300.0	5,211.0	1,650.0	173.7	27.0	2.8	7,064.5

1/ Excludes amounts for aircraft technology in 1959 and succeeding years. Amounts for NASA-NACA aircraft and space activities not separately identifiable prior to 1959.

Source: Bureau of the Budget

U.S. SPACE BUDGET - EXPENDITURES



SPACE ACTIVITIES BUDGET

1967 Budget Document
January 24, 1966
(In millions of dollars)

	New Obligational Authority			Expenditures		
	1965 (Actual)	1966 (Estimated)	1967 (Estimated)	1965 (Actual)	1966 (Estimated)	1967 (Estimated)
Federal Space Programs						
NASA*..................	5167.6	5087.9	4908.3	5035.0	5521.0	5211.0
Department of Defense.....	1579.4	1693.5	1620.7	1591.8	1640.0	1650.0
Atomic Energy Commission.	228.6	195.6	173.5	232.2	201.0	173.7
Department of Commerce:						
Weather Bureau.........	12.2	27.3	35.8	24.1	19.2	27.0
National Science Foundation.	3.2	3.6	2.9	3.0	3.5	2.8
TOTAL	6991.0	7007.9	6741.2	6886.1	7384.7	7064.5
NASA						
Manned space flight....	3452.4	3518.4	3387.5	3538.5	3810.0	3600.0
Scientific investigations.	692.7	727.1	605.3	661.6	735.0	656.0
Space applications......	83.2	95.1	100.6	89.0	101.0	100.0
Space technology.......	498.6	431.4	450.7	484.0	465.0	470.0
Aircraft technology.....	82.1	87.0	103.7	57.9	79.0	89.0
Supporting operations...	357.4	324.0	364.3	261.6	410.0	385.0
Adjusted to appropriation	+83.4	-8.1	-	-	-	-
Total.................	5249.7	5174.9	5012.0	5092.9	5600.0	5300.0

*Excludes amounts for aircraft technology.
Source: Bureau of the Budget

INDEX

A-7 58
Advanced Aerial Fire Support System (AAFSS) 59
Advanced Manned Missions 17, 18
Advanced Defense Communications Satellite Project (ADSC) 54
Advanced Research Projects Agency (ARPA) 55, 63, 128
Aeronautics 57
Aeronautics, Astronautics Coordinating Board (AACB) 66
Aeronautical Extraordinary Administrative Radio Conference (EARC) 120
AGENA 11, 25, 64
Air Force, U.S. 11, 28, 29, 34, 43, 49-69, 77, 78
All Weather Landing 114
ALOUETTE 2, 4, 20, 41
Ames Research Center 31, 66
Andover, Maine, Ground Station 117
Anti-Satellite System 4, 55
APOLLO 1, 4, 9, 10, 12-18, 22, 23, 28, 32 35, 36, 39, 44, 45, 57, 67, 68, 77, 80, 90, 92, 97, 98, 118, 121, 124
APOLLO Aplications 16-18
Applications Technology Satellites 24, 36, 39
Applied Mathematics 26
Argentina 121
Arms Control and Disarmament Agency 127-128
ASSET 61
Astronauts 10, 50, 75-79, 101
Astronomy 83, 98, 101, 103
ATLAS 11, 25, 38
Atomic Energy Commission 55, 69-73
Auroras 64, 82, 101
Automatic Picture Transmission (APT) 43, 88

BEACON 42, 55
Bioastronautics 22, 98, 99, 101
Biosatellites 4, 22
Brazil 42, 43, 121

C-5A 2, 3, 49, 57-58
C-135 39
C-141A 58, 111
Canada 2, 4, 41, 43, 64, 77, 103, 121
CENTAUR 4, 25, 38
Central Radio Propagation Laboratory 91
Cerro Tololo Inter American Observatory (Chile) 82
Civil Aeronautics Board (CAB) 96
Coast and Geodetic Survey 85, 90, 92, 103
Commerce, Dept. of 19, 67, 85-96
Command Service Module (CSM) 13-16
Communications and Tracking 34
Communications, Defense Satellite Program 51-54
Communications Satellites 3, 24, 80, 117-119
Communications Satellite Act of 1962 118, 120
Communications Satellite Corp. 2, 24, 39, 52, 80, 117, 118, 121, 124
Counterinsurgency Aircraft (COIN) 4, 59
CV-7A 111

Deep Space Network 40
Defense, Dept. of 4, 17, 19, 29, 38, 39, 44, 45, 49-69, 80, 89, 92, 96, 97, 108
Defense Supply Agency 46
DELTA 22, 25
Denmark 42, 43
Disarmament Conference 127

EARLYBIRD 2, 3, 18, 24, 80, 117, 118, 121, 124
Eastern Test Range 50, 61
ECHO 24, 85
Ecuador 77
Electronics and Control 34
Ethiopia 71
European Space Research Org. (ESRO) 2, 41, 43, 44
Exobiology 22, 99
EXPLORER 18, 19, 24, 25, 41, 55, 85, 89, 103

Extraordinary Administrative Radio Conference on Space Communications 117, 119

F-1 Engine 15
F-111A 58
Federal Aviation Agency 28, 58-61, 97, 107-115
Federal Communications Commission 97, 117-120
FIRE 32
FR-1 20
France 20, 41, 43
French National Center for Space Studies 41
Fuel Cells 11

GEMINI 1, 3, 4, 9, 10-12, 18, 22, 23, 34, 38, 42, 50, 57, 67, 68, 78, 79, 87, 92, 99, 103, 122, 124, 125
Geodetic Satellite Program 19, 55-56, 90, 103
GEOS 3, 103
Germany 41, 79
Global Commercial Communications Satellite System 118, 119
Goddard Space Flight Center 35, 39, 46, 71
Gravity Gradient Stabilization 63

Harry Diamond Laboratory 68
Helicopters 59-60
Hungary 76
Hurlburt, E.O. Center for Space Research 82

ICSU 97-101
Ikeya Seki (Comet) 105
IMP 19
India 87
International Year of the Quiet Sun (IQSY) 82, 83, 87
Iran 77
Israel 41
Italy 41, 79

Japan 101
Jet Propulsion Laboratory (JPL) 21, 40, 71

Kennedy, Cape 10, 11, 12, 14, 46, 51, 55, 75, 80, 92
Kitt Peak National Observatory 81, 83
KIWI 4, 38, 69-70

Langley Research Center 27, 28
Lasers 104
LES 14
Lewis Research Center 36
LITTLE JOE 14
Lunar Excursion Model (LEM) 13, 15, 16
Lunar Geodesy 90
Lunar Orbiter 20, 21, 25, 26
Lunar Surface Experimental Package 35

Manned Orbiting Laboratory (MOL) 1, 3, 6, 7, 49-50, 67, 68, 80, 123
Manned Spacecraft Center (MSC) 71, 92
MARINER 2, 3, 9, 20, 25, 40, 64, 76, 97, 99, 122-125
MARS 1, 2, 3, 9, 20, 21, 22, 25, 76, 97, 99
Marshall Space Flight Center 21
Materials 26, 65, 94, 95
Medicine, Space 98
Mercury, Planet 106
MERCURY, Project 99, 122
Moon 1, 3, 99

National Academy of Sciences 97-101, 110
National Aeronautics and Space Administration 9-48, 97-101, 75, 77, 80, 128
National Aeronautics and Space Council 5-9
National Airspace System 107

National Aviation Facilities
Experimental Center 108, 115
National Bureau of Standards 85, 92-95
National Meteorological Center 85, 92-95
National Radio Astronomy Observatory 81
National Science Foundation 81-83
National Environmental Satellite Center (NESC) 85, 87
Naval Research Laboratory 19, 64, 82
Navy, U.S. 25, 28
Navigational Satellites 4, 56, 85, 90
NERVA 2, 4, 69-70
Netherlands 41
New Zealand 42
NIMBUS 23, 25, 71, 80
Nuclear Test Ban Treaty 55
Nuclear Detection Satellites (VELA) 55

Orbiting Astronautical Observatory (OAO) 20, 25, 35, 93, 98
Orbiting Geophysical Observatory (OGO) 2, 4, 19, 25, 41
Orbiting Solar Observatory (OSO) 2, 4, 18, 124
OV-10 59

Pacific Missile Range (PMR) 5, 7
Paris Air Show 5, 78, 79
Pakistan 42, 43
PAGEOS 25, 90
PAGASUS 1, 2, 4, 9, 12, 103
Peru 77
PHOEBUS 2, 4, 9, 12, 69-70
PIONEER 2, 4, 21
Plumb Brook Reactor 36
Propulsion, chemical 29, 30, 62
Propulsion, solid 2, 4, 30, 63

Radiation Calibration Sphere Satellite 51, 52

SECOR 25, 66
Smithsonian Institution 77, 103-106
Smithsonian Institution Astrophysical Observatory 77, 103
SNAP 2, 4, 23, 35, 62, 70-72, 124
Sounding Rockets 98
Space Detection and Tracking System (SPADATS) 55, 57
Space Power Equipment 62, 69, 72
Space Suit 32
Space Science Board 97-101
SPACETRACK 57
SPASUR 57
START 61, 62
State, Dept. of 97, 78-80
Sterilization 22
Structures 27, 33
SURVEYOR 4, 20, 21, 25
Supersonic Transport (SST) 2, 4, 28, 95, 96, 110, 111
SYNCOM 24, 38, 44, 52, 105, 109

TELSTAR 24
THOR 25, 64
TITAN II 1, 124
TITAN IIIA 50, 51, 124
TITAN IIIC 2, 3, 38, 49-51, 64, 123
TIROS 2, 3, 23, 85, 87, 88, 124
TIROS Operational Satellite System 2, 39, 86, 88
Tracking and Data Acquisition 38, 67, 68, 77, 101, 103, 104

United Nations 75, 76, 79, 89
United States Information Agency 79, 121-125
USSR 1, 2, 3, 5, 6, 7, 42, 79, 101, 128
United Kingdom 6, 41-44, 77, 79, 103

Vandenberg, USS 56
Vandenberg AFB 57
VELA 2, 3, 55, 73, 128
Voice of America 121, 122, 128
VOSKHOD 122
VOYAGER 21, 22, 41
V/STOL 2, 29, 60, 65, 112

Weather Bureau 23, 85-96

WEST FORD 54
White Sands Missile Range (WSMR)
14, 16, 110
World Meteorological Organization
(WMO) 75, 88

X-15 4, 9, 28, 61, 73
X-19A 61
X-22A 29, 61
XB-70 2, 4, 9, 29, 58-59, 65, 66
XC-142A 60
XV-5A 60
SV-6A 60
XV-98 60

YCH-54A 112

GSA DC 66-11665